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ABACÁ-SOIL CONDITIONS IN TWO DISTRICTS OF THE PHILIPPINE ISLANDS AND THEIR RELATION TO FIBER PRODUCTION *

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TWO PLATES

INTRODUCTION

The investigations and the experiments outlined in this paper were made with the object of throwing light on what probably has been and undoubtedly will continue to be the most serious trouble connected with abacá-fiber production; namely, weak fiber.

To gather the information and the material necessary for the prosecution of the work many months were spent in the abacá districts, more especially in those of the Bicol provinces of Camarines Norte, Camarines Sur, Albay, and Sorsogon, Luzon, and in Davao Province, southeastern Mindanao. In these places large collections were made from the growing plants, of the fibers considered representative.

These districts were especially chosen as furnishing the best examples of the oldest and the newest varieties of abacá plants, as well as the finest and the weakest. The methods of production, preparation, and storage, used probably seventy-five years ago, were studied side by side with those introduced during the past two or three years.

* The soil and ash analyses reported were made by the division of soils, Bureau of Science, Manila.

The author would like to express personal thanks for all the help, coöperation, and good will he has received since beginning this work, but he feels that they would fall far short of the mark and that all of the space should be devoted to bringing out the evident satisfaction of the entire abacá industry at the inauguration of this pioneer work by the Cordage Institute of the United States. This is the more remarkable when it is understood that these investigations were made possible only through the active coöperation of Filipinos, Germans, Chinese, Spaniards, Britishers, and Americans engaged in the abacá industry, all of whom, without exception, did all they could to further the work. In the Bureau of Science and the Bureau of Agriculture, as well as in the Fiber Standardization Board, the chiefs and assistants of the various departments appealed to gave willing personal aid and assistance and undertook much of the detail work appearing here and yet to be published.

It is fundamental that plant growth is determined by the kind and the amount of the chemical substances furnished through its roots and by the surrounding conditions of moisture and climate. Serious disturbance of normal growth may result, consequently, from any change of normal conditions. This disturbance is generally manifested by disease or abnormal products, and in the case of abacá apparently by diminished resistance to disease and a weak fiber of short durability, in place of the strong, lasting fiber known all over the world as the premier cordage material.

Analyses of abacá disclose two distinct kinds of chemical constituents: inorganic, or the mineral salts taken from soil moisture by the roots; organic, or the material furnished both by the roots and by the photosynthesis of the plant itself in the leaves. These two kinds of chemical constituents combine to make the complex chemical bodies that supply the materials for plant growth and development.

MINERAL CONSTITUENTS OF ABACÁ FIBER

In order to understand better what the abacá plant has taken from the soil in the way of mineral substances necessary for its growth, ashes were made from characteristic varieties of abacá in various localities, and these ashes were analyzed for the principal mineral constituents recognized as being most important in plant growth. In preparing these ashes it was early discovered that their tendency to assume various colors during the burning of the fiber made it necessary to adopt a method

that would secure uniform results. This was especially necessary in as much as many persons have claimed a true distinction between abacá and Canton could be based solely on the differences between the color and the texture of the ashes of the respective fibers.

PREPARATION OF ABACÁ ASH

Twenty-five grams of the full length of fiber of each sample were taken, cut into small pieces, and charred in a large porcelain crucible, which was refilled about three times to complete the process. The heat was then increased (a muffle furnace was used) until the carbonaceous residue ignited and slowly burned out. The heat was again increased to low red, and the residual ashes oxidized to a permanent form without melting. After having been cooled in a desiccator and weighed, the ashes were transferred to a dry specimen tube, which was then sealed, and water-color paintings made of the ashes, as the photographs themselves could not be correctly colored.

After many experiments, it was proven that differences in amount, texture, color, and composition of the ash contents of a fiber were influenced by at least the following factors: Locality where grown; variety of abacá; maturity of the plant; grade of fiber. Other factors will be considered later. From these modifying conditions, especially the fourth one, it follows that a sample of ash is truly representative in all respects only of the fiber from which it is made, but is not representative even of the entire plant nor of that variety of abacá. The colored drawings, made from the ash specimens as mentioned above, illustrate some of the differences and similarities that appeared interesting and of possible future utility.

ASHES OF REPRESENTATIVE ABACÁ FIBERS OF THE BICOL PROVINCES

Sample 5 (Table 1) was a composite sample made up of equal parts of five varieties of abacá growing in the Bacacay district of Albay. Cleaning grade, Good to Fair.

Sample 6 (Table 1) was a composite sample made up of equal parts of five varieties of abacá, one variety selected from each of the following districts: Jovellar, Guinobatan, Manito, Bulan, and Tinapian. Cleaning grade, Good to Fair.

Samples 30, 31, 32, and 33 were taken from four representative varieties of abacá growing in the same field, Buhi district, Camarines Sur. Cleaning grade, Coarse.

TABLE 1.—*Chemical analyses of ashes of abacá-fiber samples from Bicol provinces.*

Sample No.	Silica (SiO_2).	Iron and aluminum oxides (R_2O_3).	Calcium oxide (CaO).	Magnesium oxide (MgO).	Potassium oxide (K_2O).	Sulphuric anhydride (SO_3).	Chloride (Cl).	Manganese oxide (MnO_2).	Phosphoric annydride (P_2O_5).
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5	14.06	6.30	9.19	5.43	34.65	1.00	6.08	0.14	2.01
6	9.89	6.80	8.23	3.06	42.52	0.91	5.51	2.01	1.81
30	13.00	8.70	6.48	3.39	44.65	-------	-------	1.04	2.11
31	14.55	7.20	7.51	1.84	46.28	-------	-------	1.08	1.52
32	9.75	7.30	8.19	2.74	41.63	-------	-------	1.37	1.16
33	12.65	4.10	7.51	1.33	49.81			1.00	2.02

From the figures in Table 1 it is apparent that the principal and outstanding food constituents of abacá, other than nitrogen, coming from the soil are potash, iron, alumina, lime, magnesia, and silica. Silica, recognized as a hardening and protecting material rather than as one concerned with the vital processes of growth and development, may be disregarded in the present discussion. Iron and alumina will be discussed later and attention will be given more particularly first to potash and to lime with its associated magnesia.

To prove that the last-named three salts merit attention, not only because of their food qualities, but also on account of the quantities involved, it should be remembered that conservative figures for abacá-fiber production in the Philippines during many years is 1,250,000 bales per year, or a gross weight of 154,000,000 kilograms. Analyses of eighty fiber samples show an average ash content of 1.85 per cent by weight of the fiber, the samples mentioned in Table 2 having been analyzed.

TABLE 2.—*Ash content of eighty samples of abacá fiber.*

Number of samples.	Locality.	Grade of cleaning.	Ash.	
			Average weight.	Per cent.
			g.	
27	Bicol area	Excellent	0.23	0.92
31	do	Good and fair	0.49	1.96
22	do	Coarse	0.67	2.68
Average			0.46	1.85

Taking 1.85 per cent as representing the ash content of the commercial fiber harvested, at least 1.5 per cent should be added to represent the ash from the immense amount of waste fiber and pulp discarded by the stripping knives, almost all of which is also lost to the soil. We have therefore, conservatively, over 3 per cent, or about 5,000,000 kilograms of mineral constituents in the yearly abacá crop, of which over half is composed of potash and lime salts alone. That these areas have continued to produce for fifty years and are still producing, suffering as they have been an annual loss of nearly 5,000 tons of mineral constituents essential to abacá production, seems almost impossible and, while it must make us marvel at their past fertility, it certainly also should make us fearful for the future. Not that the situation cannot be met and handled, but that up to the present neither preliminary nor experimental work has been undertaken by the Government or by private interests to demonstrate the best way of doing in a wholesale way that which obviously must be done—the reconditioning of the abacá fields. Unless such experimental work is started at once and prosecuted with vigor the task will become increasingly difficult each year.

To call attention again to the true significance of these figures, a brief description of the methods of abacá-fiber production and preparation must be given, the essential features of which are the cutting down of the entire plant; the selection from it of some 15 per cent of the outer sheaths; and the stripping of these layers under an especially arranged knife blade to produce the commercial fiber, which constitutes a little less than 2 per cent by weight of the entire plant cut down. In as much as the process of harvesting the fiber by present methods removes only about 10 or 15 per cent of the material of the entire crop, the other 85 to 90 per cent is allowed to remain on the ground, and thus become plant food again through the agency of fermentation and decay. The products of fermentation are acid in character and, when dissolved by the rains and absorbed by the soil, not only are made available as plant food but also aid materially in dissolving the soil minerals, thus changing them from potential into available food products. This cycle of changes, then, is repeated at least twice a year throughout the abacá fields. Millions of kilograms of plants are cut down but only a small part removed; the rest are left, to return to the soil through fermentation and decay and be reabsorbed by the

remaining uncut, growing plants. This process of harvesting is certainly unique and probably peculiar to abacá. That the soil is enriched and fertilized by the immense amount of organic and inorganic material spread over it semiannually is undoubtedly true and is shown by the very high percentages of humus found almost without exception in all the abacá soil analyses. It also perhaps accounts for the fact that the abacá planter, from earliest time to the present, has been content to take his semiannual crop of fiber and do nothing, absolutely nothing, in the way of plowing, cultivation, fertilization, or crop rotation, to return to the soil that which has been taken away as fiber, amounting to millions of kilograms annually.

Deeper digging into the present conditions of our abacá soils reveals several facts. The first is that the tremendous quantities of fermenting plant material left on the ground around the growing plants for months at a time form large quantities of acid products which are absorbed by the soil, making it acid or sour. This excess acidity reacts in various ways, most of which are harmful unless promptly dealt with. Some of the acid is directly absorbed by the growing abacá plants, the pernicious effects of which absorption will be described later; some of it leaches out through heavy rainfalls and disappears in the surface or subsoil run-off; much of it reacts chemically with the soil minerals, becoming neutralized and forming salts that in turn may be absorbed by the plants. The mineral that apparently acts as the great neutralizer of these acids of fermentation and decay is limestone, and in making soil analyses it has been found most convenient to measure the soil acidity in terms of lime equivalents. It is, therefore, a prime necessity for soils, where large quantities of acids are periodically spread over them, to have sufficient lime available not only to neutralize the acidity as it appears, but also to supply the heavy and constant needs of the growing crop. The roots of the plants penetrate but a relatively short distance into the surrounding soil; the movement of soil moisture is, in general, slow in heavy soils, so that it would seem advisable to apply lime or change the soil through plowing and cultivation. The Philippine planter has never changed his soil by plowing. It is, therefore, high time to examine the actual chemical condition of the soils of the large areas that have been producing abacá crops on an average of twice a year for a half century or more with practically no plowing, cultivation, or crop rotation.

The samples of surface soils, the chemical and physical analyses of which are given in Tables 3 and 4, were collected from the principal abacá districts of the Bicol provinces of Camarines Norte, Camarines Sur, Albay, and Sorsogon, at the same time and in the same locality as the fiber samples were taken from the various commercial varieties of abacá plants producing there. Care was taken to secure as representative samples of soils as possible, and the samples were invariably taken from spots equally distant from the surrounding hills of abacá; in other words, the effort was made to obtain the most favorable sample, and as far removed from local root proximity as possible. While the fields from which some of the samples were taken are comparatively young (say, ten to fifteen years under continuous crop production), most of them have probably been under crop for many years, it being no uncommon thing to find fields known to have been producing for forty to fifty years. As no study has yet been reported of soils and soil conditions in the abacá districts, and no standards of comparison were available, the only way to show the effects of abacá crops on soil was to compare old districts with new. For this reason the Davao district of Mindanao was chosen for comparison with the Bicol district, as the former is one of the newest, its fiber production per hectare several times that of the Bicol district, and its fiber the most uniformly strong and durable.

MECHANICAL ANALYSES OF ABACÁ SOILS OF THE BICOL PROVINCES

The mechanical analyses of soils here reported were made by the Schöne method as practiced by Osborne and as modified by Cox,[1] and the chemical analyses by the methods prescribed by the Association of Official Agricultural Chemists. To get their value and to understand their significance in the present instance, the following explanatory remarks may be permitted:

The roots of a growing plant are influenced to a very marked degree by the physical conditions of the soil surrounding them, for dependent on these conditions is the availability of the mineral foods, water, and air necessary for their growth. The prevailing opinion has been that abacá will grow well and produce heavily only in soils of sandy loam or even a coarser class, and these soils predominate in the Bicol district planted to abacá; yet, all the recent experience of planters in the Davao

[1] Philip. Journ. Sci. § A 6 (1911) 316.

district shows that, other conditions being favorable, even the clay and clay-loam types will produce heavy crops.

TABLE 3.—*Mechanical analyses of soils in the Bicol provinces, Luzon.*

[Water-free basis. Numbers indicate percentages.]

Serial No.	Classification.	Detritus not passing 1-mm. sieve.	(1) Coarse sand, 1–0.5 mm.	(2) Medium sand, 0.5–0.25 mm.	(3) Fine sand, 0.25–0.10 mm.	(4) Very fine sand, 0.10–0 05 mm.	(5) Silt, 0.05–0.005 mm.	(6) Clay, 0.003 mm.	Total, Nos. 1 to 6.
18	Sandy loam	------	11.6	23.9	25.2	14.1	19.3	5.9	100
34	----do	------	7.6	20.0	30.4	11.2	26.9	3.9	100
40	Clay loam	------	1.2	3.4	12.9	12.5	48.8	21.2	100
71	Silt loam	------	1.1	5.8	21.0	13.6	50.2	8.3	100
72	Fine sandy loam	------	1.5	9.8	39.8	17.8	23.9	7.2	100
73	Sandy clay	------	2.5	12.7	34.3	10.0	26.7	13.8	100
74	----do	------	1.7	10.6	23.9	14.8	34.3	14.7	100
92	Sandy loam	------	6.2	22.4	25.3	15.6	20.8	9.7	100
93	----do	------	15.2	21.2	20.9	10.4	22.8	9.5	100
123	Sand	40.3	39.1	35.3	6.1	5.1	9.7	4.7	100
124	Sand loam	29.5	11.7	25.8	26.3	10.3	22.5	3.4	100
129	Fine sandy loam	------	1.5	8.4	41.4	17.1	29.4	2.2	100
138	Sandy loam	10.9	8.6	30.6	29.9	7.2	18.5	5.2	100
164	Fine sand	------	7.6	11.6	27.3	34.2	15.3	4.0	100
171	Sandy clay	------	6.7	12.9	25.6	20.5	28.7	5.6	100
185	Sand	39.2	43.2	32.8	8.7	4.0	9.4	1.9	100
186	Clay loam	------	11.0	10.6	10.2	9.5	38.0	20.7	100
193	Silty loam	------	1.0	5.6	24.3	7.8	48.7	12.6	100
200	Fine sandy loam	------	0.2	0.6	19.1	32.9	42.0	5.2	100
	Average	------	9.4	16.0	23.8	14.2	28.2	8.4	100

TABLE 4.—*Mechanical analyses of soils, Davao Province, Mindanao.*

[Water-free basis. Numbers indicate percentages.]

Serial No.	Abacá district.	Classification.	Detritus not passing 1-mm. sieve.	Coarse sand, 1–0.5 mm.	Medium sand, 0.5–0.25 mm.	Fine sand, 0.25–0.10mm.
501	Taguia	Clay loam	None	1.8	6.9	22.7
502	Bago	Loam	----do	0.1	3.6	24.1
503	Patada	Silt loam	----do	0.2	0.3	12.7
504	Daliao	Fine sandy loam	----do	2.1	15.6	44.3
505	Bankas	Clay	----do	0.2	3.0	15.4
506	Guianga	Silt loam	----do	0.3	5.6	22.8
507	----do	Sandy clay	----do	2.6	7.0	30.0
508	Lais	----do	----do	2.7	13.3	24.7
509	Malita	Fine sandy loam	----do	0.7	10.7	40.5
511	Kumasie	----do	----do	0.2	5.8	37.3
	Average			1.09	7.18	27.45

TABLE 4.—*Mechanical analyses of soils, etc.*—Continued.

Serial No.	Abacá district.	Classification.	Detritus not passing 1-mm. sieve.	Very fine sand, 0.10–0.05 mm.	Silt, 0.05–0.005 mm.	Clay, 0.003 mm.	Total.
501	Taguia	Clay loam	None	8.3	37.2	23.1	100
502	Bago	Loam	do	9.7	44.7	17.8	100
503	Patada	Silt loam	do	25.0	53.7	8.1	100
504	Daliao	Fine sandy loam	do	15.4	14.3	8.3	100
505	Bankas	Clay	do	9.8	26.0	45.6	100
506	Guianga	Silt loam	do	10.7	51.4	9.2	100
507	do	Sandy clay	do	15.6	36.2	8.6	100
508	Lais	do	do	17.0	36.3	6.0	100
509	Malita	Fine sandy loam	do	19.7	18.4	10.0	100
511	Kumasie	do	do	17.5	32.6	6.6	100
	Average			14.87	35.08	14.33	100

The general results shown by the analyses presented in Tables 3 and 4 would also seem to substantiate the assertion that abacá can grow and produce well on soils of the heaviest as well as of the lightest type, provided only the chemical conditions are favorable and the proper variety of abacá is selected, the later being a very important consideration.

Taking for granted, then, until more evidence to the contrary has been presented, that there are suitable varieties of abacá for the many kinds of soils found in the districts of the Islands where climatic conditions are favorable for their growth, the chemical composition and conditions of these soils become of primary importance and merit the closest study.

The principal constituents of abacá ashes have been stated before and the order of their importance according to weight percentages is potash, silica, lime and magnesia, iron and alumina. Potash, comprising nearly half of the ash contents, is probably the most important mineral constituent necessary to abacá growth and development. Silica, being present always in excess in almost all soils, need not be considered here. Closely following silica, with an average of 10 per cent and more, are lime and magnesia, considered together on account of the similarity of their action. They are of special importance to the abacá planter and exporter for the reason that the more research given to the subject of the chemical constitution of the binding material of bast and pseudo-bast fibers [2] the more are

[2] Matthews, J. Merritt, Distinction of Bast and Pseudo Bast Fibers; Textile Fibers 3d ed (1916) 159, 170, 171.

chemists agreed that it is composed of a form of pectin in combination with lime and magnesia.[3]

This brings us to the question of abacá's fundamental requisite, the chemical substances necessary for making the strongest possible binding material for its fiber; for, no matter how well it may otherwise grow and thrive, if it produces weak fiber it is a failure from the commercial standpoint, and is degraded to the Canton class and called "bastard" fiber.

As has been stated before, we have no direct method of showing by chemical analysis whether the soils contain in sufficent quantities the essential substances needed by the plants for producing strong fibers, and neither the Government nor private interests appear to have established any standards for comparison. We are forced, therefore, to judge abacá soils by the standards worked out for other Philippine crops on which work has been done. Therefore, the ratings given in Tables 5 and 6 for the percentages of the various chemicals the soils contain, even though rather broad interpretation be given them and allowance made for possible special needs of abacá, are certain to give valuable information to those vitality interested. There is also a fundamental rule that appears applicable to most agricultural soils—that in order to avoid the detrimental effect of abnormal acid soil conditions plenty of lime and magnesia must be present to neutralize the acidity. A study of the analyses, especially of the soils in which the acidity is more than normal, as is true in the majority of cases in the Bicol district, indicates that the lime and magnesia rating is also low, while in the Davao district this is the case only where the crop is of many years' standing and, according to Davao practice, ready to be uprooted and replanted after a year of crop rotation.

The percentages of potash are so uniformly low in the Bicol district that it can be asserted with positiveness that there is serious disturbance to both the normal and even the present abacá growth, which must be far from normal. Even the much newer Davao soils, with careful plowing and cultivation, already show poor potash conditions in several districts. Phosphates, an essential plant food though used in comparatively small quantities and generally present in most Philippine soils, are also low in several Bicol districts. If these collected soil

[3] Matthews, J. Merritt, Composition of Binding Material; Textile Fibers, 387, 388. Ehrlich, F., Chem. Ztg. 41 (1917) 197–200. Abstracted in Chem. Abs. 11: 2898.

samples are at all representative (and they were collected with that end in view), the only conclusion we can get from their analyses and from the abacá-plant requirements as shown by their ashes is that the older abacá-soil areas, of which the Bicol area is an example, are decidedly lacking in potash and, as a general rule, also in the antiacid constituents, lime and magnesia.

The Davao soils, on the contrary, due perhaps to their relatively few years under crop and also to the constant plowing, cultivation, and often plant rotation to which they have been subjected, still compare very favorably, with few exceptions, with the standards laid down for fertile, well-balanced soils. It was found practically impossible to secure exact data regarding the number of years during which the various fields, from which the soil samples were taken, in the Bicol area, had been producing abacá crops. With few exceptions probably most of the fields have been producing for twenty years or longer; that some have been producing for over fifty years could be authenticated.

Where two samples of soils were collected from the same district, the effort was always made to secure them from widely separated localities or from localities the soil characteristics and topography of which were very different. In the Manito district sample 40 was taken from the west, No. 193 from the east side of the peninsula. In the Juban district both samples were from very old plantations, No. 73 from rolling to hilly land and No. 74 from a field located near Cadacan River. Sample 123 came from the south side of the Ligao-Tabaco Road, in the Bantayan district, and No. 124 was taken on the north side well up on the rolling hillsides, not far from Mount Masaraga. The Bacacay district is separated by the Malilipot-Libog Road into two distinct sections topographically. Sample 164 was secured well up on the side hills of Mayon Volcano, and No. 171 came from one of the old plantations near the town of Bacacay, where the land is flat and the soil very different from that of the hillsides above.

It was pointed out above that the abacá plant needs an abundant supply of lime to counteract undue soil acidity and to furnish the necessary supply of lime used by the plant, as one of the essential constituents of the binding material of the cells to form both individual fiber elements and also to bind these elements together into fiber bundles. Attention was also called to the fact that the soil samples collected in the older fields were gen-

TABLE 5.—*Chemical analyses of soils of the Bicol provinces of Camarines Norte, Camarines Sur, Albay, and Sorsogon.*[a]

Serial No.	Abacá district.	Topography.	Nitrogen (N_2).	Rating.	Phosphoric anhydride (P_2O_5).	Rating.	Lime (CaO).	Rating.	Magnesia (MgO).	Rating.
18	Daet, Camarines Norte	Flat	0.847	P	0.229	G	0.980	L	0.27	vL
34	Buhi, Camarines Sur	Rolling	0.313	P	0.232	G	0.72	L	0.85	L
40	Manito, Albay	Hilly	0.150	G	0.124	F	0.25	L	0.45	L
71	Sorsogon, Sorsogon	Flat	0.265	P	0.096	L	0.84	L	0.97	L
72	Irosin, Sorsogon	Hilly	0.337	P	0.225	G	1.08	L	0.58	L
73	Juban, Sorsogon	do	0.240	P	0.215	G	0.78	L	0.80	L
74	do	Rolling	0.335	P	0.254	G	0.37	vL	0.60	L
92	Jovellar, Albay	Hilly	0.120	G	0.066	L	0.82	L	0.59	L
93	Guinobatan, Albay	Sloping	0.326	P	0.225	G	3.83	G	0.99	L
123	Bantayan, Albay	Rolling	0.260	G	0.135	F	3.93	G	1.15	L
124	do	Hilly	0.065	L	0.186	F	2.46	G	1.17	L
129	Goa, Camarines Sur	do	0.546	P	0.400	G	1.19	L	0.73	L
138	Tiwi, Albay	Flat	0.313	P	0.222	G	2.64	F	1.28	L
164	Bacacay, Albay	Hilly	0.141	G	0.193	F	4.30	G	0.95	L
171	do	Flat	0.264	P	0.132	F	4.24	G	0.65	L
185	Ligao, Albay	Hilly	0.351	P	0.112	F	4.32	G	0.97	L
186	Putiao, Sorsogon	Flat	0.239	P	0.088	L	0.50	L	0.32	vL
193	Manito, Albay	Rolling	0.334	P	0.325	G	0.18	vL	0.17	vL
200	Bulan, Sorsogon	Flat	0.166	G	0.074	L	0.46	vL	0.22	vL

Serial No.	Abacá district.	Topography.	Potash (K_2O).	Rating.	Humus.	Rating.	Acidity as calcium carbonate ($CaCO_3$).	Rating.	Manganese (MnO_2).	Rating.
18	Daet, Camarines Norte	Flat	0.17	L	5.27	P				
34	Buhi, Camarines Sur	Rolling	0.19	L	6.82	P	0.009	s a		F
40	Manito, Albay	Hilly	0.08	v L	3.43	G	0.012	f a	0.05	G
71	Sorsogon, Sorsogon	Flat	0.19	L	2.80	G	0.012	f a	0.10	G
72	Irosin, Sorsogon	Hilly	0.07	v L	5.98	P	0.015	f a	0.02	L
73	Juban, Sorsogon	do	0.21	L	4.20	P	0.012	f a	0.12	G
74	do	Rolling	0.19	L	3.79	G	0.032	a	0.11	G
92	Jovellar, Albay	Hilly	0.20	L	1.91	F	0.012	f a	0.06	F
93	Guinobatan, Albay	Sloping	0.30	F	2.98	G	0.008	s a	0.03	L
123	Bantayan, Albay	Rolling	0.12	v L	2.57	G	0.009	s a	0.02	L
124	do	Hilly	0.12	v L	2.20	G			0.05	F
129	Goa, Camarines Sur	do	0.20	L	6.98	P				
138	Tiwi, Albay	Flat	0.12	v L	5.38	P	0.002	n	0.04	F
164	Bacacay, Albay	Hilly	0.13	v L	3.48	G			0.03	L
171	do	Flat	0.22	L	2.41	G			0.02	L
185	Ligao, Albay	Hilly	0.13	v L	3.06	v L			0.06	F
186	Putiao, Sorsogon	Flat	0.23	L	1.12	F			0.35	P
193	Manito, Albay	Rolling	0.17	v L	2.41	G			0.37	P
200	Bulan, Sorsogon	Flat	0.13	v L	0.89	L			0.12	G

[a] The figures represent percentages, based on water-free samples. The percentages were obtained through digesting the soil with strong hydrochloric acid. Key to acidity rating: f a, fairly acid; s a, slightly acid; n, neutral. Key to rating of mineral contents of soils as compared with standard Philippine agricultural soils: F, Fair; G, Good; L, Low; v L, very Low; P, Plenty.

TABLE 6.—*Chemical analyses of soils of Davao Province.*[a]

Serial No.	Abacá district.	Topography and years under abacá crop.	Nitrogen (N_2).	Rating.	Phosphoric anhydride (P_2O_5).	Rating.	Lime (CaO).	Rating.	Magnesia (MgO).	Rating.
501	Taguia	Flat; 13 years	0.326	P	0.149	F	0.65	L		
502	Bago	Sloping; 20 years	0.189	G	0.145	F	0.47	v L		
503	Patada	Flat; 19 years	0.157	G	0.200	G	3.34	G		
504	Daliao	Flat; many	0.128	G	0.247	G	0.18	v L		
505	Bankas	Sloping; few	0.228	P	0.346	P	4.87	P		
506	Guianga	Flat; few	0.336	P	0.238	G	0.72	L		
507	do	Sloping; old	0.262	P	0.134	F	0.74	L		
508	Lais	Sloping; 15 years	0.189	G	0.254	G	3.65	G		
509	Malita	Flat; 13 years	0.132	G	0.219	G	2.18	G		
511	Kumasie	Sloping; 15 years	0.145	G	0.127	F	3.63	G		

Serial No.	Abacá district.	Topography and years under abacá crop.	Potash (K_2O).	Rating.	Humus.	Rating.	Acidity as calcium carbonate ($CaCo_3$).	Rating.	Manganese (MnO_2)	Rating.
501	Taguia	Flat; 13 years	0.29	L	1.96	F	0.010	s a	0.36	G
502	Bago	Sloping; 20 years	0.37	F	1.62	F	0.006	s a	0.41	G
503	Patada	Flat; 19 years	0.96	P	0.70	L	0.002	n	0.13	F
504	Daliao	Flat; many	0.13	v L	0.95	L	0.012	f a	0.12	F
505	Bankas	Sloping; few	0.32	F	1.84	F	Alk.	alk.	0.15	F
506	Guianga	Flat; few	0.26	L	1.93	F	0.006	s a	0.22	F
507	do	Sloping; old	0.12	v L	1.67	F	0.005	n	0.15	F
508	Lais	Sloping; 15 years	0.58	G	0.79	L	0.004	n	0.08	L
509	Malita	Flat; 13 years	0.63	G	0.85	L	0.005	n	0.55	G
511	Kumasie	Sloping; 15 years	0.56	G	0.59	L	0.001	n	0.54	G

[a] The figures above represent percentages, based on water-free samples. The percentages were obtaned through digesting the soil with strong hydrochloric acid. Key to acidity rating: f a, fairly acid; s a, slightly acid; n, neutral. Key to rating of mineral contents of soils as compared with standard Philippine agricultural soils: F, Fair; G, Good; L, Low; v L, very Low; P, Plenty.

erally found abnormally acid in reaction, despite the fact that precautions were taken to collect the samples where no fermenting waste was present. Where fiber harvesting has been going on and the ground is covered with a layer of fermenting abacá waste the acid conditions must be acute, and the dissolving action of the rains would take these acid solutions directly to the abacá roots before they could be neutralized by the small quantities of lime and magnesia generally present. In such case the acids would be absorbed by the roots, and taken up and distributed as such, or in some modified form, to various parts of the plant, including the fibers. It has long been recognized by fiber chemists that all acids, except the very weakest, have a weakening and deleterious effect on the binding substance of all fibers of the class that includes abacá. If these two assertions are correct then we should find an excess of acidity in the fibers coming from acid soils, and their tensile strength would also be less than that of fibers from normal soils. Experiments to show the average acidity and tensile strength of the collected fibers of the Bicol provinces compared with those of the Davao district were carried out as follows:

All fibers used in these experiments were dried quickly to prevent growth of molds and bacteria. The tensile strength, or breaking point, of the fibers was determined by testing accurately weighed fiber bundles exactly a half meter long in a Louis Schopper fiber-testing machine and measuring their breaking point in kilograms. In this way the tensile strength in kilograms per gram per meter of fiber was accurately determined; from ten to twenty tests on each sample of fiber were made and the average was taken.

The acidity of each sample of fibers was determined by using the same fiber that had been broken in the tensile-strength tests and adding to it enough fiber from the same abacá sample to make the weight 10 grams. These were cut into half-inch pieces, put in a 750 cubic centimeter round-bottomed flask, and heated on a water bath one hour with 500 cubic centimeters of distilled water, under frequent shaking. At the end of the hour as much of the solution as possible was poured off into an Erlenmeyer flask and the solution titrated with 0.1 *N* sodium hydroxide (NaOH), using phenolphthalein as indicator and titrating to a faint pink color on shaking. Many modifications were tried to make the experiment more accurate; but, as relative rather than absolute total amounts of free and soluble acids were desired, the figures given in Table 7 are correct

within 0.1 or 0.2 cubic centimeter, and are those found by the described method, and indicate the cubic centimeter of 0.1 *N* sodium hydroxide (NaOH) used to neutralize 10 grams of fiber. It is to be noted that the average acidity for six samples of fiber, collected on one plantation where the abacá was grown between rows of large coco trees and where the soil was found to be acid and deficient in both lime and potash, was over 1 cubic centimeter. Were these six not counted the average acidity for the Davao area would be 0.57 cubic centimeter instead of 0.64 cubic centimeter. Were a selection made of the samples of fiber grown only on acid soils low in lime, potash, and phosphates and their figures compared with those of fibers from normal soils the differences would be more marked, but even as given the differences in both tensile strength and acidity are sufficient to indicate a serious disturbance to normal abacá growth in poor soil and to give a working hypothesis as to its cause.

TABLE 7.—*Samples of fiber.*

Number of fiber samples tested.	Locality.	Average tensile strength.	Average acidity in cc. 0.1 *N* calcium carbonate (NaOH).
		kg.	
66	Four Bicol provinces	48.65	1.08
37	Davao	59.40	0.64

CHEMICAL CHARACTERISTICS OF WEAK FIBER [4]

There is also another phase to this excess soil acidity and lack of mineral foods that merits serious consideration. The analyses of various abacá ashes, given elsewhere in this paper, show the high average alumina content of from 5 to 7 per cent. It has been shown by plant pathologists that an excess of alumina in plant tissues indicates an unhealthy condition of the plant, so that the substitution of alumina for other minerals, such as lime or potash, becomes a question of necessity and not one of choice. In the study and comparison of weak and strong fibers it was also noticed early that strong fiber was characterized by its resistance to the dissolving or disintegrating action of hot water, in comparison with weak fiber, which has a relatively high percentage of water-soluble substance.

[4] Weak in the sense that the fiber came from a weak-fibered variety of abacá, but not weakened through fermentation or mold action.

CHEMICAL DIFFERENCES BETWEEN STRONG AND WEAK FIBERS

DIFFERENCES IN ASH COMPOSITION

Two samples of fiber from neighboring localities were selected, each of Good to Fair cleaning, No. 765 coming from a weak variety of abacá and No. 779 from a strong, standard fiber. Fifteen grams of each were carefully weighed, cut into short pieces, and incinerated at a low heat in a muffle furnace, as previously described. When the ashes had assumed a permanent color they were removed from the furnace, cooled in a desiccator, and weighed. The weights and chemical analyses are given in Table 8.

TABLE 8.—*Weights and chemical analyses of ash from two samples of abacá.*

No.	Ash.		Chemical analysis.		
	Weight.	Color.	Silica (SiO_2).	Alumina (Al_2O_3).	Lime (CaO).
	Per cent.		*Per cent.*	*Per cent.*	*Per cent.*
765	0.4105 or 2.7	Buff brown; powdery	28.03	9.47	10.66
779	0.4315 or 2.9	Deep gray; granular	16.15	4.46	12.35

DIFFERENCES IN ORGANIC MATTER SOLUBLE IN WATER

One hundred grams of each fiber were cut into fine pieces, and extracted with 1,000 cubic centimeters of warm distilled water for twenty-four hours. The extract was filtered off from each and used for the following determinations:

Acidity.—An aliquot part of each extract was titrated with 0.1 *N* sodium hydroxide (NaOH) to a faint pink color with phenolphthalein an indicator. Total acidity for 10 grams of fiber, measured in terms of 0.1 *N* sodium hydroxide (NaOH), was 3 cubic centimeters for No. 765 and 2 cubic centimeters for No. 779.

Neutral and basic lead acetate precipitates.—It was found that, by means of a mixture of neutral and basic lead acetate, water-soluble constituents of abacá fibers could be precipitated, washed, and thus purified for further study. Aliquot parts of the two extracts were accordingly precipitated with a slight excess of a mixture of neutral and basic lead acetate solution and the light-colored voluminous precipitates filtered and then washed until the wash water was free from lead acetate. The precipitates were then suspended in distilled water, the lead precipitated by hydrogen sulphide as lead sulphide and filtered off, and washed

with distilled water until the filtrate was no longer acid to litmus. The united filtrates were then evaporated, first on the water bath and later in a vacuum desiccator to constant weight and weighed.

	No. 765.	No. 779.
Weight of residue, grams	1.4938	0.5082
Residue, per cent	1.76	0.60

Qualitative examinations of the hot-water extracts of strong and weak fibers have so far shown them to consist of varying quantities of higher organic and presumably fatty acids, both free and combined as salts with alumina, lime, iron, and potash. In the residue from weak fibers aluminum was found to predominate largely over the other bases, while in the residue from strong fiber calcium and potash were in excess.

SUMMARY

For the most part, present conditions in the abacá areas of the Islands are of long standing rather than new or novel. We are thus reaping the results of the omissions and commissions of the abacá growers for the past fifty years, and these have been brought into prominence on account of the scientific developments of most of the other branches of the industry, after fiber has been produced.

The production of abacá fiber is unique by the fact that the soil is made to produce the same crop for an indefinite period without either plowing or cultivation being practiced (except in one district) or fertilization attempted beyond the addition to the soil of large quantities of abacá waste left to ferment in the fields after the fiber harvest.

The results of this practice are: On the soil, a steady and heavy exhaustion of the necessary plant-food minerals and a consequent permanent acid condition; on the plant, a lack of essential mineral salts on which the plant depends for proper growth and development and for the maintenance of normal resistance to disease. This is indicated by the low average yield per hectare of the older abacá districts; on the fiber, both an excess acidity that always produces short durability and an enforced substitution of necessary salts by inferior ones resulting in a loss of tensile strength.

The benefits of the modern practices of abacá production in the Davao district are shown by the relatively better condition of the soil, the increased yield of fiber per hectare, and the uniformly high quality of the fiber.

ILLUSTRATIONS

Plate 1

Figs. 81 to 89. Upper row. Ashes from the fiber of eight varieties of abacá; Good to Fair cleaning, growing in the Masarauag section of the Guinobatan district, Albay Province, Luzon. Showing somewhat close conformity of colors and amounts with one another.

2 to 10. First section of lower row. Ashes from the fiber of varieties of abacá furnishing the commercial fiber from the Daet district, Camarines Norte, Luzon; all fiber cleaned to Excellent grade. No. 2, variety Antiguo, mature; No. 3, variety Samoro, mature; and No. 10, variety Alinsanay, mature, were growing in the same field within short distances of each other. To show the effect of age on the color of the ash compare No. 3, Samoro mature, with No. 4, Samoro immature, and No. 7, Samoro overmature. Number 2 and No. 8 are both Antiguo mature, but from different localities; Nos. 3 and 9 are Samoro mature, but from different localities.

30 to 33. Ashes from the fiber of four varieties of abacá growing together in the Buhi district, Camarines Sur, Luzon; named, respectively, Samokid, Samorong itom, Samorong pula, and Salampago; cleaning grade, Coarse.

Plate 2

Figs. 95 to 104. Ashes from fiber of four varieties of abacá, Fair to Coarse cleaning, from another section of the Guinobatan district, Albay.

108 and 113. Ashes from fiber of two varieties of abacá, Amokid and Itom, Fair to Coarse cleaning; from the Bantayan district, Albay, south of the Ligao-Tabaco Road.

117 and 121. Ashes from two varieties of abacá, Amokid and Puti, Fair to Coarse cleaning; from the northern end of the Bantayan district, Albay.

125 and 168. Ashes from fibers of two varieties of abacá from the Goa-Lagonoy district, Camarines Sur; fiber of No. 168, Coarse cleaning.

135 to 168. Ashes from fibers of abacá from the Tiwi-Horovan district, Albay; Fair to Coarse cleaning.

176 to 180. Ashes from fibers of three varieties of abacá from the Putiao district, Albay; Fair to Coarse cleaning.

PLATE 1.

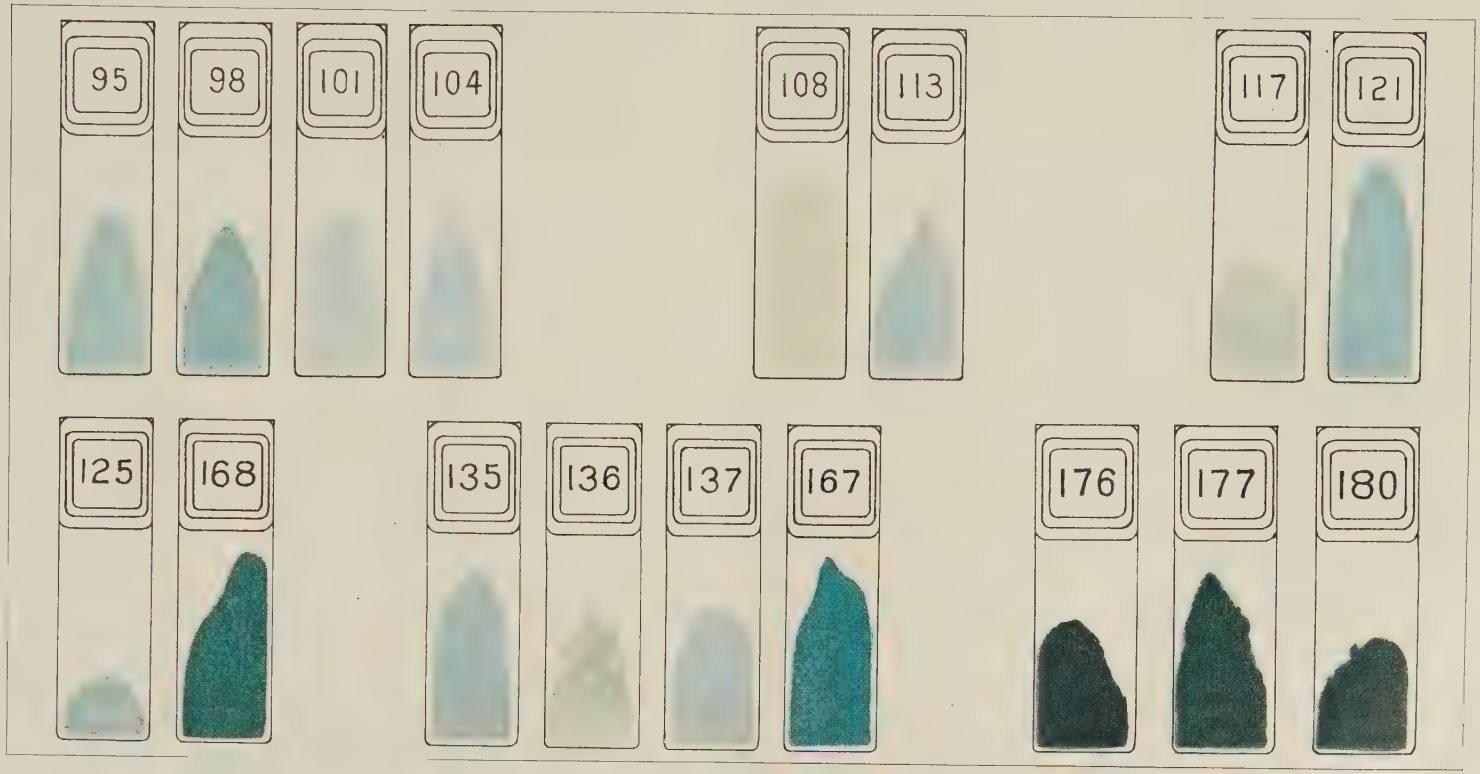

PLATE 2.

THE TENSILE STRENGTH OF ABACÁ FIBERS IN RELATION TO THEIR ACIDITY

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It is not generally known that there are certain organic acids that occur naturally in abacá fibers. No work that we have been able to locate has been reported in the scientific literature dealing with these acids.

This paper is a report of the experiments performed at the Bureau of Science, Manila, in the attempt to discover: (1) What relationship exists between the tensile strength of a sample of abacá fiber and the amount of acid present; (2) whether there is any mathematical connection between speed and amount of loss of tensile strength of an abacá-fiber sample during storage and its acid content.

RELATIONSHIP BETWEEN TENSILE STRENGTH AND ACID CONTENT

In order to determine how much variation in moisture exists when abacá fibers of various cleaning grades are subjected to the fluctuations in humidity found in the laboratory, five samples of different grades of cleaning were taken from the abacá storage room, where they had been hanging for months, put in a desiccator and immediately weighed. The abacá storage room is a closed dark room that contains several large open pans of anhydrous calcium chloride. The calcium chloride is renewed each week. This storage room was prepared in the manner described, not with the intention of keeping the abacá samples bone dry, but merely with the expectation of avoiding any excess of moisture in the fibers during storage.

The five samples of abacá used in this experiment, after being weighed, were placed in Petri dishes in a laboratory where the windows were left open day and night. The samples were left exposed for seventeen days, and were weighed once or twice

TABLE 1.—*Weight in grams of abacá samples in an open laboratory, November, 1927.*

Grade of cleaning.	Nov. 10.	Nov. 11.	Nov. 12.	Nov. 14.	Nov. 15[a]	Nov. 16[a]	Nov. 17.	Nov. 18.	Nov. 19[a]	Nov. 21.	Nov. 22.	Nov. 23.	Nov. 25.	Nov. 26.
WEIGHTS TAKEN AT 8 A. M.														
C	-------	-------	-------	5.3355	5.3392	5.3842	5.4295	5.3816	5.4303	5.4300	5.4232	5.4050	5.3578	5.3299
F	-------	-------	-------	3.0100	3.0127	3.0603	3.1068	3.0592	3.1042	3.0985	3.0878	3.0772	3.0336	3.0011
J_2	-------	-------	-------	5.4682	5.4713	5.5100	5.5600	5.5122	5.5629	5.5557	5.5477	5.5345	5.4992	5.4736
L	-------	-------	-------	6.1250	6.1275	6.1895	6.2415	6.1806	6.2398	6.2369	6.2239	6.2075	6.1550	6.1200
DM	-------	-------	-------	3.1872	3.1866	3.2177	3.2357	3.2112	3.2354	3.2354	3.2285	3.2200	3.1996	3.1888
WEIGHTS TAKEN AT 3 P. M.														
C	5.3412	5.3464	5.2708	5.3182	5.3912	5.4285	5.3928	5.3966	5.4857	5.4126	5.3832	5.3131	5.3095	5.3339
F	3.0122	3.0242	2.9582	2.9921	3.0512	3.1110	3.0765	3.0650	3.1519	3.0840	3.0549	2.9927	2.9879	3.0057
J_2	5.4613	5.4750	5.4000	5.4522	5.5245	5.5665	5.5141	5.5251	5.6122	5.5342	5.5108	5.4438	5.4387	5.4655
L	6.1200	6.1366	6.0457	6.1050	6.1942	6.2490	6.1900	6.1973	6.3480	6.2150	6.1820	6.1000	6.0913	6.1205
DM	3.1838	3.1915	3.1522	3.1800	3.2200	3.2418	3.2065	3.2185	3.2529	3.2239	3.2113	3.1850	3.1708	3.1862

[a] Rain.

a day to ascertain the changes in moisture content. Table 1 shows the fluctuations in weight.

After seventeen days the samples were put in an electric drying oven at 105° C., and dried to constant weight. Calculations made on the weights obtained show that the percentage of moisture in the samples varied according to the figures given in Table 2.

TABLE 2.—*Percentage of moisture in abacá samples.*

Grade.	Moisture in abacá in dark, partially dry storage room.	In open laboratory.		
		Least moisture in abacá.	Most moisture in abacá.	Moisture in abacá on the last day of exposure.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
C	9.40	8.28	11.87	9.36
F	12.40	10.84	16.52	12.22
J_2	9.84	8.81	12.26	9.91
L	10.15	9.05	13.38	10.16
DM	9.40	8.52	11.35	9.50

The results indicated prove that there is only a relatively small variation in the percentage of moisture present in abacá samples exposed to the air for seventeen days. The difference in percentage between the minimum and the maximum water content was only around 3 per cent, except in the case of the fiber of grade F. A careful examination of Table 1 shows that the fluctuations in water content are slow and gradual changes, and that the maximum water content of the fibers occurred only after thirty hours of continuous rain. We were unable to obtain a moisture-conditioning room which would have ensured a definite and exact control of the water content of the abacá samples. We adopted, for all of the experiments described in this paper, the method used by the Fiber Standardization Board of the Philippine Islands, and we believe it gave only a small percentage of error. The following method was the one employed:

All abacá samples were kept in the dark semidry room previously described, until ready for use. The sample selected for experimentation was exposed in the laboratory for only six hours, if the day was rainy, and for twenty-four hours under ordinary weather conditions. Drawing our conclusions from the figures in Table 1, we believe the variation in moisture content of the samples used did not exceed 1 per cent, and the consistent and uniform results obtained seem to confirm this belief.

In order to determine what difference in tensile strength might be expected with a variation of moisture content of 1 per cent, the following experiment was devised:

Forty bundles of fibers were selected from the same sample, and prepared for tensile-strength determinations according to methods adopted by the Fiber Standardization Board. Twenty fiber bundles were placed over an open dish of water, without being allowed to come in contact with it, and left for twelve hours. The tensile strength was determined on ten of the fibers by the method described later, and the moisture content was determined on the remaining ten fibers. The tensile strength was 53.87 kilograms, calculated on the basis of the breaking force required on a gram of fiber weight, which was a meter in length, and the average moisture content was 9.9 per cent.

The remaining twenty fiber bundles were put in an electric drying oven at 103° C. for two hours. Half of these fibers were used for tensile-strength determinations, and the other half for moisture determinations. The average tensile strength was 58.08 kilograms per gram of fiber weight per meter of length. The average moisture content of these fibers was 0.89 per cent. There was a change of 4.19 kilograms in tensile strength for 9.08 per cent loss of moisture, or about 0.45 kilogram change in tensile strength for 1 per cent of moisture.

The figures for tensile strength and percentage of elasticity given in this report were determined in a 50-kilogram Louis Schopper tensile-strength machine. The figures given for each sample are the average of from ten to twenty determinations made on each sample. The fibers for the separate determinations were selected from different parts of the sample, according to a definite method, adopted by the Fiber Standardization Board as giving uniform results. The tensile-strength numbers in the tables of this report are the average of at least ten determinations and were obtained by calculation from the actual figures obtained in the Louis Schopper machine, and they represent the number of kilograms necessary to break fiber weighing 1 gram and measuring a meter in length.

The elasticity numbers show the average percentage of stretch, when fiber bundles 20 centimeters long were used.

The acidity numbers were determined in the following way: Approximately 10 grams of abacá fiber were selected from different parts of the sample, and exactly 10 grams were weighed out. The weighed sample was cut finely, placed in an Erlenmeyer flask with 500 cubic centimeters of distilled water, and

heated one hour on the steam bath. The liquid was poured from the fiber, and the total acid content of the decanted liquid and washings was determined by titration with 0.1 *N* sodium hydroxide (NaOH), using phenolphthalein as indicator. Additional tests made on the fiber residue proved that very little acid remained. We are using these acid figures, however, as indicating the relative acid content of the abacá samples examined, rather than the total acidity.

After making many determinations, we noticed a striking relationship between the tensile strength and elasticity, and the relative acid content of a given abacá sample. As the tensile strength and elasticity decrease, the relative acid content increases.

While we would not attempt at this stage of the investigation to state that the acidity of an abacá sample is a determining or causative factor of its tensile strength, our tables show a surprisingly uniform parallelism between the tensile strengths and the relative acid content.

In order to make our comparisons more easily seen, we have classified all the samples into three groups; namely, the samples with tensile strengths of from 50 to 59 kilograms, inclusive; the samples with tensile strengths of 40 to 49 kilograms, inclusive, and the samples with tensile strengths below 40 kilograms.

There were too few samples with tensile strengths above 60 kilograms to make a fair basis of comparison, so these figures were not included.

Eighty-two abacá samples (Table 3) showed an average tensile strength of 54.87 kilograms; an average percentage of elasticity of 2.50; and an average acidity of 0.89 cubic centimeter in terms of 0.1 *N* sodium hydroxide (NaOH).

Seventy-eight abacá samples (Table 4) showed an average tensile strength of 44.0 kilograms; an average percentage of elasticity of 2.37; and an average acidity in terms of 0.1 *N* sodium hydroxide (NaOH) of 1.31 cubic centimeters.

Thirty-three abacá samples (Table 5) showed an average tensile strength of 35.45 kilograms; an average percentage of elasticity of 2.11; and an average acidity in terms of 0.1 *N* sodium hydroxide (NaOH) of 1.73 cubic centimeters.

For an average decrease in tensile strength of approximately 10 kilograms, there is also a decrease in percentage of elasticity of from 0.13 to 0.26; and an increase of acidity of 0.42 cubic centimeters in terms of 0.1 *N* sodium hydroxide (NaOH).

TABLE 3.—*Fiber samples having tensile strength of 50 to 59 kilograms, with their corresponding acidity.*

No.	Origin.	Variety.	Tensile strength.	Elasticity.	Acidity in terms of 0.1 *N* NaOH.
			kg.	*Per cent.*	*cc.*
525	Libbey, Davao	Lauan	56.9	2.56	0.58
526	do	Tangonong	54.5	2.60	0.62
527	do	Libuton	50.7	2.37	0.58
528	do	Maguindanao	57.4	2.65	0.60
530	Bago, Davao	Tangonang	56.4	2.52	0.70
531	do	Libuton	50.9	2.36	0.60
532	do	Maguindanao	56.6	2.75	0.50
533	do	Bungalanon	58.6	2.40	0.50
538	Patada, Davao	do	58.1	2.32	0.50
539	do	Tangongon	56.5	2.22	0.49
540	do	Maguindanao	55.8	2.77	0.55
541	do	Libuton	56.0	2.21	0.60
542	do	Lauanan	57.0	2.66	0.50
550	Daliao, Davao	Maguindanao	56.0	2.52	0.30
551	do	Tangongon	56.2	2.48	0.30
552	do	Bungalanon	56.5	2.24	0.30
553	do	Maguindanao	54.3	2.81	0.50
554	do	Tangongon	53.6	2.49	0.76
555	do	Bungalanon	58.2	2.47	0.80
573	Malita, Davao	Abacá	59.8	2.23	0.70
574	do	do	57.8	2.20	0.80
596	Jolo, Jolo Island	Lanut agutay	57.7	2.13	0.90
753	Ligao, Albay	Abacá	50.5	2.37	0.60
756	Libog, Albay	Taguiltil	56.6	2.88	1.30
757	do	Bungoranon	58.3	2.63	0.60
758	do	do	56.1	2.35	1.10
760	Pandan, Albay	Amokid	51.0	2.58	0.30
761	do	Abacá	59.0	2.43	0.60
762	do	Amokid	59.0	2.55	0.30
763	do	Abacá	55.4	3.00	0.40
780	Tabaco, Albay	Samorong itom	53.0	2.79	0.60
781	do	do	55.7	2.66	0.30
785	do	Canton	56.1	2.35	0.40
794	Bacacay, Albay	Samorong puti	53.6	2.60	1.20
800	Libog, Albay	Samorong itom	53.7	2.64	0.40
801	do	do	54.8	2.64	0.40
805	do	Canton	58.7	2.35	0.60
808	do	do	50.7	2.30	1.10
809	do	do	53.3	2.60	0.50
804		do	52.9	2.46	0.60
812	Bacon, Sorsogon	Samorong itom	52.1	2.86	0.70
814	Gubat, Sorsogon	do	52.0	2.86	0.50
815	do	do	51.4	2.86	0.40
820	Rapurapu, Albay	Abacá	51.2	2.44	2.10
832	Ligao, Albay	do	53.3	2.50	1.20
840A	Casiguran, Sorsogon	do	54.8	2.37	1.20
840B	do	do	59.5	2.62	1.20

TABLE 3.—*Fiber samples having tensile strength of 50 to 59 kilograms, with their corresponding acidity*—Continued.

No.	Origin.	Variety.	Tensile strength.	Elasticity.	Acidity in terms of 0.1 *N* NaOH.
			kg.	*Per cent.*	*cc.*
202	Daet, Camarines Norte	Antiguo	57.4	2.60	5.50
203	do	Samoro	57.4	2.71	4.50
204	do	do	59.4	2.65	0.60
210	do	Alinsanay	55.2	2.57	0.80
213	do	do	58.1	2.28	0.55
214	do	do	57.2	2.52	0.45
222	Ligao, Albay	Kidit	59.4	2.49	0.30
224	do	Samoro	59.8	2.36	0.50
235	Tinapian, Albay	Buranom puti	55.1	2.92	0.95
244	Sorsogon, Sorsogon	Pulá	57.2	2.67	1.00
250	Juban, Sorsogon	Lagonoy	51.9	2.40	0.90
251	do	do	56.2	2.40	0.40
253	do	Puti	53.0	2.45	0.90
254	do	do	50.9	2.58	1.00
256	do	Lagonoy	50.7	2.31	0.90
260	do	Samoro puti	55.8	2.26	0.60
262	do	Binagacay	52.7	2.26	0.60
263	do	Lagnis	50.6	2.10	0.60
264	do	Samoro pulá	57.8	2.40	0.30
266	Patad, Sorsogon	Isarog	59.3	2.70	1.00
270	do	Pulá	54.8	2.61	0.70
283	Masaraw, Albay	Rayado	50.2	2.49	2.10
288	do	Amoraon	50.4	2.34	1.60
295	Guinobatan Experiment Station, Albay.	Puti	53.9	2.38	0.60
296	do	do	56.0	2.47	1.00
298	do	Itom	53.6	2.58	1.60
299	do	do	53.7	2.62	1.50
301	do	Bagacayon	51.1	2.56	1.00
302	do	do	52.0	2.80	1.20
309	Tabaco, Albay	Puti	50.0	2.99	1.70
313	Bantayan, Albay	Itom	50.8	2.53	1.20
327	Goa, Camarines Sur	do	59.7	2.42	0.60
332	Bacacay, Albay	Binohuran	56.9	2.48	0.90
341	Tabaco, Albay	Abacá	51.8	2.47	1.00
347	do	do	52.3	2.67	1.00
379	Putiao, Sorsogon	puti	52.4	2.82	1.20
380	do	Samoro puti	53.2	2.00	1.00
381	do	do	50.2	2.08	0.90
397	Bulan, Sorsogon	Abacá	54.4	1.99	0.60
399	do	do	50.4	2.00	1.50
	Total abacá fibers		4,499.4	205.52	73.33
	Average abacá fibers		54.87	2.50	0.89
	Total Canton fibers		271.7	12.06	3.20
	Average Canton fibers		54.3	2.40	0.64

TABLE 4.—*Fiber samples having tensile strength of 40 to 49 kilograms, with their corresponding acidity.*

No.	Origin.	Variety.	Tensile strength.	Elasticity.	Acidity in terms of 0.1 *N* sodium hydroxide (NaOH).
			kg.	*Per cent.*	*cc.*
741	Rapurapu, Albay	Canton J_2	45.6	2.42	1.50
743	do	Canton I	45.9	2.39	0.90
745	do	Canton M_1	41.6	2.28	1.20
748	do	Canton G	44.9	2.26	1.20
750	Ligao, Albay	Abacá	47.2	2.38	0.30
751	do	do	44.3	2.41	0.70
752	do	do	47.7	2.77	0.70
759	Sorsogon, Sorsogon	Amokid	48.7	2.62	1.00
766	Libon, Albay	Samorong puti	48.2	2.50	1.90
767	do	do	45.3	2.51	2.00
768	do	Canton	42.9	2.23	2.30
796	Bacacay, Albay	Abacá	47.8	1.28	0.40
799	Libog, Albay	do	44.5	2.75	0.90
802	do	Canton puti	42.8	2.36	1.50
803	do	do	42.8	2.49	0.50
806	do	Canton pulá	40.9	2.16	2.00
807	do	do	45.9	2.46	0.70
810	Bacon, Sorsogon	do	48.4	2.79	0.70
811	do	do	48.4	2.67	1.40
813	do	Abacá	46.7	2.62	0.90
819	Legaspi, Albay	do	40.8	2.59	2.80
821	Donsol, Sorsogon	do	49.6	2.25	4.70
833	Kabankalan, Occidental Negros	Mixed	48.9	1.94	1.80
841–c	Casiguran, Sorsogon	Abacá	47.7	2.36	1.20
848	Southern Albay	Balones	43.8	2.28	3.80
201	Daet, Camarines Norte	Alinsanay	43.1	2.52	0.90
211	do	do	47.4	2.67	0.60
212	do	do	46.8	2.36	0.75
216	do	Abacá	47.8	2.64	0.60
230	Buhi, Camarines Sur	Samokid	41.5	2.53	1.20
232	do	Samorong pulá	40.4	2.24	1.70
233	do	Salampago	40.6	2.15	0.90
236	Tinapian, Albay	Buranom pulá	48.7	2.24	0.80
237	do	Bagcacayon puti	48.5	2.65	0.85
238	do	Samina itom	46.7	2.67	1.00
241	Sorsogon, Sorsogon	Puti	49.4	2.46	0.90
246	do	Amokid	40.5	2.31	1.20
248	Juban, Sorsogon	Agpas	42.8	2.78	1.60
252	do	Isarog	45.9	2.46	1.20
275	Jovillar, Albay	Samina	41.8	2.57	1.50
276	do	Samoro itom	47.9	2.32	1.20
277	do	Bagcacayon	40.6	2.78	1.30
278	do	Samoro puti	49.1	2.39	1.20
279	do	Cañaraon	41.4	2.62	1.30
281	Guinobatan, Albay	Puti	44.5	2.66	2.10
282	do	Amokiron	46.7	2.45	2.00
284	do	Binagacay	45.8	2.21	1.60
285	do	Itom	48.2	2.46	0.90

TABLE 4.—*Fiber samples having tensile strength of 40 to 49 kilograms, with their corresponding acidity*—Continued.

No.	Origin.	Variety.	Tensile strength.	Elasticity.	Acidity in terms of 0.1 *N* sodium hydroxide (NaOH).
			kg.	*Per cent.*	*cc.*
287	Guinobatan, Albay	Pulá	49.9	2.33	1.50
289	do	Burit	40.0	2.32	0.70
290	do	Abacá	45.9	2.44	1.10
291	do	do	45.6	2.32	1.40
297	Guinobatan Experiment Station, Albay.	Itom	49.4	2.45	1.00
300	do	Bagacayan	43.4	2.27	1.80
303	do	Tomatagacan	48.6	2.68	1.20
304	do	do	46.9	2.46	1.00
305	do	do	47.4	2.53	2.40
306	do	Abacá	42.2	2.15	1.40
307	do	do	44.8	2.16	0.80
308	Bantayan, Albay	Amokid	40.2	1.97	1.60
310	do	Pulá	43.1	2.09	1.00
311	do	Aggikikon	46.7	2.64	1.00
314	do	Itom	43.9	2.33	1.20
317	do	Amokid	46.6	2.27	0.90
318	do	Pulá	46.8	2.30	1.90
319	do	Agonoy	44.7	2.36	1.90
320	do	Itom	44.2	2.30	2.60
322	do	Aggikikon	45.8	2.40	1.20
333	Bacacay, Albay	Itom	40.0	2.02	1.30
335	Tiwi, Albay	do	49.6	2.18	2.00
336	do	Pulá	49.5	2.40	1.30
339	Tabaco, Albay	Abacá	47.2	2.38	0.90
340	do	do	49.5	2.42	1.00
342	do	do	49.6	2.51	1.00
343	do	do	40.0	2.08	1.30
353	Bacacay, Albay	Torotagácan	41.6	2.38	1.30
355	do	Bulao	41.0	2.26	0.90
361	do	Pulayog	40.5	2.24	1.00
362	do	Puti	44.9	2.43	0.90
363	do	Itom	41.9	2.34	1.20
366	do	Canton	43.8	1.94	1.80
374	Tabigian, Albay	Mindanao	45.7	2.42	1.50
375	do	Pulá	40.9	2.22	1.30
376	Putiao, Sorsogon	Samina	44.0	2.39	0.90
377	do	Samoro puti	49.7	2.47	0.80
378	do	Alaon	43.7	2.09	0.80
383	do	Amokid	47.4	2.20	1.00
392	Manito, Albay	Puti	41.3	1.83	1.60
767	Libon, Albay	Abacá	45.3	2.51	2.00
806	Libog, Albay	Canton pulá	40.9	2.16	2.00
798	do	Abacá	47.8	2.68	0.60
	Total, excluding Cantons		3,534.5	185.62	102.60
	Average abacá fibers		44.0	2.37	1.31
	Total, excluding abacás		574.8	30.61	17.70
	Average Canton fibers		44.2	2.35	1.43

TABLE 5.—*Fiber samples having tensile strength of below 40 kilograms with their corresponding acidity.*

No.	Origin.	Variety.	Tensile strength.	Elasticity.	Acidity in terms of 0.1 *N* sodium hydroxide (NaOH).
			kg.	*Per cent.*	*cc.*
727	Catanduanes, Albay	Canton mix	39.2	2.26	6.60
728	do	do	30.2	2.33	6.70
737	Rapurapu, Albay	Canton	21.4	1.13	1.40
738	do	do	24.5	2.21	3.10
739	do	do	29.7	2.01	2.60
740	do	do	30.9	1.92	2.10
744	do	do	27.8	2.09	1.50
746	do	do	33.4	1.18	1.30
747	do	do	36.6	2.13	1.30
749	Jolo	do	25.0	1.45	2.80
754	Ligao, Albay	Abacá	37.6	2.08	0.70
764	Pandan, Albay	do	34.6	2.44	2.00
769	Libon, Albay	Canton	38.8	2.11	3.00
770	Caholhon, Albay	Abacá	27.7	2.15	2.00
771	do	do	29.1	2.07	4.70
774	do	Canton itom	23.1	2.33	1.70
775	do	do	24.3	1.87	4.10
778	Tabaco, Albay	Samorong itom	39.0	2.40	0.90
779	do	do	29.4	2.06	0.90
782	do	Canton puti	29.5	2.14	2.00
783	do	do	23.6	1.86	5.30
786	Pandan, Albay	Amokid	28.0	2.63	0.70
787	do	do	26.1	2.01	1.70
788	Bacacay, Albay	Canton puti	27.4	1.90	6.00
789	do	do	35.7	3.50	0.80
791	do	Canton pulayog	27.1	1.79	6.30
795	do	Abacá	37.2	2.54	1.50
816A	Pandan, Albay	Mixed A and C	23.4	1.72	2.20
817	Southern Albay	Abacá	38.0	2.48	2.70
818	do	do	38.5	2.62	1.10
823	Negros	Balones	22.8	2.42	1.90
834	Rapurapu, Albay	Canton	39.4	2.14	1.80
842A	Goa, Camarines Sur	Abacá	39.6	1.93	4.20
844	Legaspi, Albay	do	38.4	1.06	1.00
845	Tabaco, Albay	do	37.9	2.15	4.40
846	do	Canton	28.0	1.80	4.30
847	Camarines Norte	do	11.9	1.87	6.30
849	do	do	33.8	2.03	5.20
850	do	do	28.1	1.60	5.80
228	Iriga, Camarines Sur	Abacá	31.2	1.88	2.10
231	Buhi, Camarines Sur	Samorong itom	37.2	2.15	1.20
239	Tinapian, Albay	Canton	30.4	1.70	1.20
247	Juban, Sorsogon	Agpas	35.9	2.05	1.20
294	Guinobatan, Albay	Puti	38.2	2.03	0.80
312	Bantayan, Albay	do	38.3	1.91	2.30
321	do	do	29.1	1.94	0.90

TABLE 5.—*Fiber samples having tensile strength of below 40 kilograms with their corresponding acidity*—Continued.

No.	Origin.	Variety.	Tensile strength.	Elasticity.	Acidity in terms of 0.1 *N* sodium hydroxide (NaOH).
			kg.	*Per cent.*	*cc.*
330	Bacacay, Albay	Canton pula	30.5	1.74	1.40
331	do	Canton puti	26.8	1.37	1.70
337	Tiwi, Albay	Puti	36.5	2.33	1.70
348	Tabaco, Albay	do	38.6	2.31	1.90
350	Bacacay, Albay	Itom	39.0	2.39	1.20
351	do	Binanguran	36.3	2.22	0.90
352	do	Puti	37.3	2.17	1.70
354	do	Agonoy	37.5	2.52	1.10
356	do	Moronganom	37.4	2.09	1.20
358	do	Morong datu	26.5	1.86	1.10
359	do	Pacol	20.2	2.24	2.60
360	do	Abacá	24.9	1.84	1.20
367	Horoan, Albay	do	37.7	1.96	0.90
368	Caramoan Peninsula	do	36.0	1.94	4.00
369	Pandan, Albay	do	31.2	2.31	1.20
382	Putiao, Sorsogon	Pacol	24.4	1.23	1.30
388	Manito, Albay	Canton puti	34.3	1.70	2.20
389	do	Pulá	30.6	1.37	1.00
390	do	Tipontipon	39.2	1.50	1.00
387	Guinobatan, Albay	Abacá	28.9	1.96	2.60
391	Manito, Albay	Puti	34.9	1.31	1.00
398	Bulan, Sorsogon	Canton	39.5	1.79	2.00
401	Rapurapu, Albay	do	26.1	1.37	1.50
408	Masaraw, Albay	Canton puti	34.2	2.00	2.00
409	do	Abacá	38.1	2.04	1.10
395	Caramoan Peninsula, Camarines Sur.	Canton	22.8	1.42	3.30
	Total abacá fibers		1,170.4	69.83	57.30
	Average abacá fibers		35.45	2.11	1.73
	Total Canton fibers		932.7	59.96	92.00
	Average Canton fibers		30.0	1.87	2.96

THE RELATION BETWEEN TENSILE STRENGTH AND ACID CONTENT FOR CANTON FIBERS

Canton fibers are obtained from hybrid plants and are apparently crosses between abacá and banana.

The five Canton fiber samples that are included in Table 3 have an average tensile strength of 54.3 kilograms; an average percentage of elasticity of 2.40; and an average acidity in terms of 0.1 *N* sodium hydroxide (NaOH) of 0.64 cubic centimeters.

Thirteen Canton fiber samples (Table 4) show an average tensile strength of 44.2 kilograms; an average percentage of

elasticity of 2.35; and an acid content in terms of 0.1 *N* sodium hydroxide (NaOH) of 1.43 cubic centimeters.

Thirty-one Canton fiber samples (Table 5) show an average tensile strength of 30 kilograms; an average percentage of elasticity of 1.87; and an average acidity in terms of 0.1 *N* sodium hydroxide (NaOH) of 2.96 cubic centimeters.

In the case of Canton fibers there is also an increase of acid content as the tensile strength decreases, but it is not so uniform as in the case of abacá. Only a few Canton fibers are represented in Tables 3 and 4, so that these results are to be expected.

Nearly all Canton fibers have a tensile strength below 40 kilograms; they are included in this article because the average figures for Canton fibers as found in Table 5 are of value as supporting evidence in distinguishing between true abacá fibers and Canton fibers, in case of dispute in fiber identification.

The average figures for the Canton fiber samples (Table 5) are not in themselves to be taken as conclusive proof of identity, since some abacá samples show the same figures; but these numbers are often very useful in confirming other, more-important tests that have indicated that the fiber under investigation is probably a Canton fiber.

RATE OF LOSS OF TENSILE STRENGTH DURING STORAGE AND THE ACID CONTENT

An experiment was undertaken to show whether or not a mathematical relationship exists between the speed and the amount of loss of tensile strength in abacá fibers during storage and the acid content. The fibers used for this experiment were kept six months or longer in the dark, semidry storage room described above. The moisture content of the fibers in this room ranged from 9 to 11 per cent. The tensile strengths were determined twice on the same sample after an interval of storage of six months or longer. An acid determination was also made on the same sample usually at the end of the period of storage. Our results, doubtless, would have been more valuable had we made several acid determinations on each sample at intervals during the period of storage. At the beginning of this research work, however, we did not foresee the relationship between tensile strength and acidity. At present, we have no way of knowing whether the acid content of a given sample varied or not during the period of storage. It is conceivable that some of the fibers that showed the greatest loss of tensile strength

but which, at the time of titration, had a low acid content may have had a high quantity of acid at the beginning of storage. These acids may have dissolved, or chemically changed the binding material of the middle lamella of the abacá during storage, thus lowering the tensile strength of the fiber. During this process the acids themselves may have been used up, so that only a small amount of acid was left in the perished fiber.

It is also possible that deterioration of abacá may have been caused more by the nature of the acids present than by their quantity. Certain acids are formed during bacterial fermentation, and it is possible that small quantities of the acid products of fermentation may have a more deleterious effect on abacá than larger amounts of those organic acids that are normally present. We wish to emphasize, at this point, that the greater part of the samples tested were not commercial samples, but were gathered personally in the field, and were stripped and dried under conditions that would make fermentation impossible.

Drawing our conclusions from the data now at hand, we have not found that any regular mathematical relationship exists between the rate of loss of tensile strength during storage and the amount of acid present. In no case, however, did we find abacá with an unduly high acid content, but that the fiber either already had a low tensile strength, or else it showed a much lowered tensile strength after long storage.

SUMMARY

1. The natural acid content of abacá is greater in fibers having low tensile strengths.

2. As the tensile strengths of abacá samples decrease about 10 kilograms per gram of weight per meter of length, the natural acidity of the fiber increases about 0.42 cubic centimeter for each 10 grams. The acidity is measured in terms of 0.1 *N* sodium hydroxide (NaOH) using phenolphthalein as an indicator.

3. The natural acid content is also higher for Canton fibers with a low tensile strength, but the mathematical relationship between the tensile strength and the acid content is less definite for these hybrids than it is for true abacá.

4. Loss of tensile strength in abacá during storage is affected by the acid content, but as yet no definite mathematical relationship between the rate of loss of tensile strength and the acid content has been discovered.

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TABLE 6.—*Showing changes of tensile strength during storage.*

No.	Origin.	Variety.	Tensile strength.	Elasticity.	Date.	Acidity in terms of 0.1 *N* sodium hydroxide (NaOH).	Date.
			kg.	*P. ct.*		*cc.*	
525	Libbey, Davao	Lauan	56.9	2.56	Oct. 27, 1926	0.58	Aug. 5, 1927.
525	do	do	53.9	2.09	Aug. 2, 1927		
528	do	Magindanao	57.4	2.65	Oct. 30, 1926	0.60	Aug. 5, 1927.
528	do	do	53.9	2.26	Aug. 4, 1927		
533	Bago, Davao	Bungalanon	58.6	2.40	Nov. 2, 1926	0.50	Aug. 8, 1927.
533	do	do	56.0	2.15	Aug. 9, 1927		
541	Patada, Davao	Libuton	56.0	2.21	Jan. 10, 1927	0.60	Aug. 15, 1927.
541	do	do	53.9	2.03	Aug. 12, 1927		
542	Bago, Davao	Lauan	57.0	2.66	Jan. 10, 1927	0.50	Aug. 15, 1927.
542	do	do	54.5	2.25	Aug. 15, 1927		
550	Daliao, Davao	Magindanao	56.0	2.52	Nov. 24, 1926	0.30	Aug. 18, 1927.
550	do	do	52.7	2.28	Aug. 17, 1927		
555	do	Bungalanon	58.2	2.47	Dec. 27, 1926	0.80	Sept. 9, 1927.
555	do	do	54.3	2.15	Sept. 8, 1927		
557	Kumasie, Davao	Magindanao	62.9	2.38	Sept. 10, 1927	1.20	Sept. 13, 1927.
557	do	do	59.4	2.11	Sept. 21, 1927		
564	do	Libuton	67.3	2.51	Jan. 25, 1927	1.00	Sept. 6, 1927.
564	do	do	63.1	1.89	Sept. 13, 1927		
565	Lais, Davao	Bungalanon	60.2	2.37	Jan. 26, 1927	0.50	Sept. 6, 1927.
565	do	do	57.7	1.90	Sept. 21, 1927		
567	Malita, Davao	Baguisanon	66.8	2.41	Feb. 3, 1927	0.50	Sept. 6, 1927.
567	do	do	62.0	1.94	Sept. 23, 1927		
569	do	Magindanao	64.2	2.63	Feb. 3, 1927	0.50	Sept. 6, 1927.
569	do	do	60.0	2.28	Sept. 23, 1927		
570	do	Bungalanon	65.9	2.46	Feb. 4, 1927	0.40	Sept. 6, 1927.

570	----do----	----do----	62.2	2.01	Sept. 26, 1927	----------	
571	----do----	Opuopus	68.5	2.45	Feb. 4, 1927	0.30	Sept. 6, 1927.
571	----do----	----do----	65.7	1.88	Sept. 26, 1927	----------	
572	----do----	Tangongon	61.6	2.65	Feb. 4, 1927	0.50	Sept. 6, 1927.
572	----do----	----do----	58.8	2.04	Sept. 26, 1927	----------	
575	----do----	Magindanao	60.4	2.17	Feb. 10, 1927	1.20	Sept. 6, 1927.
575	----do----	----do----	55.7	1.47	Sept. 26, 1927	----------	
742	Rapurapu, Albay	Canton J	44.4	2.54	Dec. 4, 1926	0.90	Dec. 4, 1926.
742	----do----	----do----	41.3	2.43	Mar. 25, 1927	----------	
743	----do----	Canton I	45.9	2.39	Dec. 4, 1926	0.90	Dec. 4, 1926.
743	----do----	----do----	42.5	2.33	Mar. 25, 1927	----------	
748	----do----	Canton G	44.9	2.26	Dec. 4, 1926	1.20	Dec. 4, 1926.
748	----do----	----do----	41.9	2.32	Mar. 29, 1927	----------	
766	Libon, Albay	Abacá samorong puti	48.2	2.50	Apr. 4, 1927	1.90	Oct. 28, 1927.
766	----do----	----do----	45.9	2.39	June 6, 1927	----------	
771	Caholhon, South	Abacá	29.1	2.07	Apr. 6, 1927	4.70	Oct. 28, 1927.
771	Catanduanes	----------	25.8	1.70	July 7, 1927	----------	
791	Bacacay, Albay	Canton	27.1	1.79	Apr. 13, 1927	6.30	Nov. 1, 1927.
791	----do----	Pulayog	22.7	1.68	June 17, 1927	----------	
817	Legaspi, Albay	----------	38.0	2.48	Jan. 24, 1927	2.70	Jan. 24, 1927.
817	----do----	----------	35.8	2.04	June 24, 1927	----------	
840B	Casiguran, Sorsogon	----------	59.5	2.62	Mar. 28, 1927	1.20	Mar. 28, 1927.
840B	----do----	----------	57.4	2.73	Apr. 1, 1927	----------	
236	Tinapian Albay	Bungaranon	48.7	2.24	Oct. 28, 1925	0.80	Mar. 28, 1927.
236	----do----	Pula	45.0	2.11	Aug. 30, 1927	----------	
241	Sorsogon, Sorsogon	Puti	49.4	2.46	Oct. 30, 1925	0.90	Mar. 28, 1927.
241	----do----	----do----	46.3	1.81	Aug. 30, 1927	----------	
253	Juban, Sorsogon	----do----	53.0	2.45	Nov. 4, 1925	0.90	Sept. 19, 1927.
253	----do----	----do----	50.6	2.06	Aug. 30, 1927	----------	
266	Patad, Sorsogon	Isarog	59.3	2.70	Nov. 11, 1925	1.00	Sept. 19, 1927.
266	----do----	----do----	55.9	2.09	Aug. 30, 1927	----------	

TABLE 6.—*Showing changes of tensile strength during storage*—Continued.

No.	Origin.	Variety.	Tensile strength.	Elasticity.	Date.	Acidity in terms of 0.1 *N* sodium hydroxide (NaOH).	Date.
			kg.	*P. ct.*		*cc.*	
282	Masaraw, Albay	Amokiron	46.7	2.45	Nov. 13, 1925	2.00	Sept. 19, 1927.
282	do	do	43.4	1.90	Aug. 31, 1927		
531	Bago, Davao		50.9	2.36	Nov. 1, 1926	0.60	Aug. 8, 1927.
531	do	do	48.5	2.09	Aug. 8, 1927		
245	Sorsogon, Sorsogon		62.2	2.46	Nov. 2, 1925	0.45	Aug. 8, 1927.
245	do		57.6	2.22	Aug. 30, 1927		
529	Bago, Davao	Lauan	60.6	2.64	Oct. 30, 1926	0.50	Aug. 8, 1927.
529	do	do	53.6	2.10	Aug. 6, 1927		
530	do	Tangonong	56.4	2.52	Nov. 1, 1926	0.70	Aug. 8, 1927.
530	do	do	47.6	2.17	Aug. 6, 1927		
543	Patada, Davao	Pulahan	61.6	2.48	Nov. 4, 1926	0.80	Aug. 15, 1927.
543	do	do	56.3	2.05	Aug. 15, 1927		
559	Kumasie, Davao	Putian	61.4	2.51	Jan. 15, 1927	0.50	Sept. 13, 1927.
559	do	do	56.3	2.48	Sept. 10, 1927		
560	do	Ponokan	60.4	2.52	Jan. 15, 1927	1.00	Sept. 6, 1927.
560	do	do	52.7	2.14	Sept. 12, 1927		
561	do	Baguisanon	60.3	2.28	Jan. 18, 1927	1.20	Sept. 13, 1927.
561	do	do	48.6	1.57	Sept. 2, 1927		
562	do	Tangongon	63.0	2.46	Jan. 22, 1927	1.40	Sept. 6, 1927.
562	do	do	51.1	1.87	Sept. 12, 1927		
563	do	Bungalanon	66.7	2.44	Jan. 22, 1927	1.10	Sept. 14, 1927.
563	do	do	60.3	1.92	Sept. 13, 1927		
568	Malita, Davao	Buntot	64.0	2.45	Feb. 3, 1927	0.60	Sept. 6, 1927.
568	do	do	56.8	1.73	Sept. 23, 1927		
597	Jolo	Lanut itom	75.7	2.94	Mar. 3, 1927	0.60	Sept. 6, 1927.
597	do	do	70.1	2.84	Sept. 27, 1927		

741	Rapurapu, Albay	Canton J_2	45.6	2.42	Mar. 25, 1926	1.50	Dec. 4, 1926.
741	do	do	40.5	2.19	June 4, 1927		
747	do	Canton K	36.6	2.13	Dec. 4, 1926	1.30	Dec. 4, 1926.
747	do	do	30.1	2.24	Mar. 27, 1927		
767	Libon, Albay	Abacá, samorong puti	45.3	2.51	Apr. 4, 1927	2.00	Oct. 28, 1927.
767	do	do	38.2	2.02	June 6, 1927		
769	do	Canton minay or samina	38.8	2.11	Apr. 4, 1927	3.00	Oct. 28, 1927.
769	do	do	33.5	1.81	June 6, 1927		
788	Bacacay, Albay	Canton	27.4	1.90	Apr. 12, 1927	6.00	Oct. 29, 1927.
788	do	Puti	20.5	1.51	June 17, 1927		
807	Libog, Albay	Canton pulá or itom-baba	45.9	2.46	Apr. 20, 1927	0.70	Nov. 1, 1927.
807	do	do	36.5	1.98	June 8, 1927		
840A	Casiguran, Sorsogon	Abacá	54.8	2.37	Mar. 28, 1927	1.20	Nov. 1, 1927.
840A	do	do	48.2	2.39	Apr. 29, 1927		
841C	do	do	47.7	2.36	Mar. 28, 1927	1.20	Nov. 1, 1927.
841C	do	do	36.5	2.05	Apr. 1, 1927		
237	Tinapian, Albay	Bagcacayon	48.5	2.65	Oct. 28, 1925	0.85	Nov. 1, 1927.
237	do	Puti	40.2	1.89	Aug. 30, 1927		
248	Juban, Sorsogon	Agpas with fruit	42.8	2.78	Nov. 2, 1925	1.60	Nov. 1, 1927.
248	do	do	33.7	1.71	Aug. 30, 1927		
252	do	Isarog	45.9	2.46	Nov. 4, 1925	1.20	Sept. 19, 1927.
252	do	do	33.2	1.66	Aug. 30, 1927		
260	do	Samoro puti	55.8	2.26	Nov. 6, 1925	0.60	Oct. 26, 1927.
260	do	Pananon	47.5	1.96	Aug. 30, 1927		
264	do	Puti	57.8	2.40	Nov. 6, 1925	0.30	Oct. 26, 1927.
264	do	do	45.7	1.78	Aug. 30, 1927		
276	Jovellar, Albay	Samorong	47.9	2.32	Nov. 13, 1925	1.20	Sept. 19, 1927.
276	do	Itom	23.9	1.39	Aug. 31, 1927		
277	do	Bagcacayon	40.6	2.78	Nov. 13, 1925	1.30	Sept. 19, 1927.
277	do	do	28.8	1.43	Aug. 31, 1927		
278	do	Samoro	49.1	2.39	Nov. 13, 1925	1.20	Sept. 19, 1927.
278	do	Puti	31.2	1.56	Aug. 31, 1927		

TABLE 6.—*Showing changes of tensile strength during storage*—Continued.

No.	Origin.	Variety.	Tensile strength.	Elasticity.	Date.	Acidity in terms of 0.1 *N* sodium hydroxide (NaOH).	Date.
			kg.	*P. ct.*		*cc.*	
283	Masaraw, Albay	Rayado	50.2	2.49	Nov. 13, 1925	2.10	Sept. 19, 1927.
283	do	do	43.3	2.10	Aug. 31, 1927		
526	Libbey, Davao	Tangonong	54.5	2.60	Oct. 27, 1926	0.62	Aug. 5, 1927.
526	do	do	53.3	2.07	Aug. 3, 1927		
540	Patada, Davao	Magindanao	55.8	2.77	Jan. 8, 1927	0.55	Aug. 15, 1927.
540	do	do	54.3	2.49	Aug. 12, 1927		
551	Daliao, Davao	Tangongon	56.2	2.48	Nov. 11, 1926	0.50	Aug. 19, 1927.
551	do	do	54.7	2.26	Aug. 18, 1927		
552	do	Bungalanon	56.5	2.24	Dec. 14, 1926	0.30	Aug. 22, 1927.
552	do	do	54.8	2.02	Aug. 22, 1927		
554	do	Tangongon	53.6	2.49	Dec. 24, 1926	0.76	Sept. 7, 1927.
554	do	do	52.3	2.43	Sept. 6, 1927		
573	Malita, Davao	do	59.8	2.23	Feb. 7, 1927	0.70	Sept. 7, 1927.
573	do	do	59.4	1.74	Sept. 26, 1927		
595	Jolo, Jolo	Lanut puti	60.2	2.69	Mar. 3, 1927	0.90	Sept. 6, 1927.
739	Rapurapu, Albay	Canton L_2	29.7	2.01	Dec. 4, 1927	2.60	Dec. 4, 1926.
739	do	do	28.4	2.00	May 23, 1927		
738	do	Canton DL	24.5	2.21	Dec. 4, 1926	3.10	Dec. 4, 1926.
738	do	do	23.8	1.86	May 23, 1927		
740	do	Canton L_1	30.9	1.92	Dec. 4, 1926	2.10	Dec. 4, 1926.
740	do	do	29.6	1.47	Mar. 23, 1927		
744	do	Canton M_2	27.8	2.09	Dec. 4, 1927	1.50	Dec. 4, 1926.
744	do	do	27.4	2.09	Mar. 25, 1927		
773	Caholhon, South	Abacá	60.2	2.64	Apr. 6, 1927	0.80	Oct. 28, 1927.
773	Catanduanes	Lupis	58.7	2.60	July 7, 1927		

779	Tabaco, Albay	Samorong	29.4	2.06	Apr. 8, 1927	0.90	Oct. 29, 1927.
779	....do	Itom	27.7	1.90	June 9, 1927		
795	Bacacay, Albay	Abacá samorong puti	37.2	2.54	Apr. 16, 1927	1.50	Nov. 1, 1927.
795	....do	....do	36.3	2.09	May 11, 1927		
806	Libog, Albay	Canton	40.9	2.16	Apr. 20, 1927	2.00	Nov. 1, 1927.
806	....do	Pulá or itom	39.2	2.00	June 18, 1927		
816A	Pandan, Albay	....do	23.4	1.72	Apr. 22, 1927	2.20	Nov. 1, 1927.
816A	....do	....do	22.6	1.61	June 23, 1927		
235	Tinapian, Albay	Buranom	55.1	2.92	Oct. 27, 1927	0.95	Nov. 1, 1927.
235	....do	Puti	53.5	2.53	Aug. 30, 1927		

TABLE 7.—*Loss of tensile strength during storage, with corresponding acidity of abacá samples.*

SAMPLES HAVING TENSILE STRENGTH OF 50 KILOGRAMS AND ABOVE.

No.	Tensile strength lost during storage. Loss of from 1 to 1.90 kilograms.	0.1 *N* sodium hydroxide (NaOH) necessary to neutralize acids of 10 grams of abacá.	No.	Tensile strength lost during storage. Loss of from 2 to 4.90 kilograms.	0.1 *N* sodium hydroxide (NaOH) necessary to neutralize acids of 10 grams of abacá.	No.	Tensile strength lost during storage. Loss of 5 kilograms and above.	0.1 *N* sodium hydroxide (NaOH) necessary to neutralize acids of 10 grams of abacá.
	kg.	*cc.*		*kg.*	*cc.*		*kg.*	*cc.*
526	1.20	0.62	525	3.00	0.58	529	7.00	0.50
540	1.50	0.55	528	3.50	0.60	530	8.80	0.70
551	1.50	0.50	533	2.60	0.50	543	5.30	0.80
552	1.70	0.30	541	2.10	0.60	559	5.10	0.50
554	1.30	0.76	542	2.50	0.50	560	7.70	1.00
573	0.40	0.70	550	3.30	0.30	561	11.70	1.20
595	0.70	0.90	555	3.90	0.80	562	11.90	1.40
773	1.50	0.80	557	3.50	1.20	563	6.40	1.10
235	1.60	0.95	565	2.50	0.50	568	7.20	0.60
			253	2.40	0.90	597	5.60	0.60
			266	3.40	1.00	840A	6.60	1.20
			564	4.20	1.00	260	8.30	0.60
			567	4.80	0.50	264	12.10	0.30
			569	4.20	0.50	283	6.90	2.10
			570	3.70	0.40			
			571	2.80	0.30			
			575	4.70	1.20			
			245	4.60	0.45			
			572	2.80	0.50			
			840B	2.10	1.20			
			531	2.40	0.60			
Total	11.40	5.58		69.00	14.13		110.60	12.60
Average	1.26	0.62		3.23	0.673		7.82	0.87
SAMPLES HAVING TENSILE STRENGTH OF 40 TO 49 KILOGRAMS.								
			766	2.30	1.90	767	7.10	2.00
			236	3.70	0.80	841C	11.20	1.20
			241	3.10	0.90	237	8.30	0.85
			282	3.30	2.00	248	9.10	1.60
						252	12.70	1.20
						276	24.00	1.20
						277	11.80	1.30
						278	17.90	1.20
Total				12.40	5.60		102.10	10.55
Average				3.10	1.40		12.76	1.32
SAMPLES HAVING TENSILE STRENGTH OF BELOW 40 KILOGRAMS.								
779	1.70	0.90	771	3.30	4.70			
795	0.90	1.50	817	2.20	2.70			
816A	0.80	2.20						
Total	3.40	4.60		5.50	7.40			
Average	1.13	1.53		2.75	3.70			

FERMENTATION AS AFFECTING THE QUALITY OF PHILIPPINE ABACÁ

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ONE PLATE

INTRODUCTION

According to the nomenclature adopted by the United States Department of Agriculture "Philippine abacá" designates the fiber produced from the plant *Musa textilis* Née and differentiates it from the other twenty and more fibers known commercially as hemp, which are grown in various parts of the world. In as much as the fiber of *Musa textilis* is now produced in Borneo, Java, and Sumatra somewhat extensively the prefix "Philippine" designates the fiber produced only in the Philippine Islands.

The word "abacá" apparently first appears historically in Pigafetta's classic diary of Magellan's Trip Around the World in 1519. In giving a list of the native articles in common use and the words used for them as found on Cebu Island, he says: "For the cloth with which they cover themselves, abacá." This cloth, woven from abacá fiber, is still extensively woven and worn in the southern Philippines.

Abacá is indigenous to the Philippines. That it is endemic and that the production of the fiber has been a monopoly up to the present are certain. The million and more bales of commercial fiber annually exported from the Islands are produced from many varieties of this one species of *Musa* as well as from apparently other more or less closely allied species, whose relationship to the true abacá is yet to be determined.

As a result of business stagnation following the World War many thousand bales of abacá fiber were stored in Manila and provincial warehouses for periods varying from a few months

to more than two years. When this fiber was exported considerable quantities were found on arrival to be more or less deteriorated in both color and tensile strength, and consequently it brought into prominence as never before the problem of quality deterioration. Preliminary investigations of the commercial methods of fiber production and storage begun some three years ago indicated that most of the fiber deterioration started during the period of its production in the provinces and was augmented and completed afterwards by storage in warehouses and ships.

Investigations in the laboratory, following those made in the field, showed that this quality deterioration could often be measured chemically and that this measurement will give valuable information as to the kind and amount that has taken place even before it is evinced through lowering of tensile strength and while an acceptable color of the fiber is still present.

The causes and the results of fiber deterioration are many and varied; some are accidental, while others are fundamental defects of the present system of production, but among the latter not one has caused the damage that can be legitimately ascribed to the lack of systematic and complete drying of the freshly stripped fiber; and, in order that the work described below may be the better understood, the essential steps in the commercial production of abacá fiber and the far-reaching results following the same are here briefly recapitulated.

To secure the maximum amount of fiber with the minimum expenditure of labor and time, the outside layer only of each of the long, fleshy leaf stems (which overlapping, form the stalk, or trunk, of the abacá plant) is pulled off from the underlying pulpy portion. This outside fibrous layer, in strips of varying width and thickness and comprising some 15 per cent of the weight of the entire trunk, is known as "tuxie" and its removal is the first step in the production of the true fiber which appears when the tuxies are in turn passed under a stripping knife to remove pulp, juice, outside skin, and short, weak fiber. The completeness of this process of cleaning the fiber is determined by the kind of knife used as well as by the pressure exerted by it on the tuxie strip. If the knife blade is sharp and the pressure sufficient, only fiber of excellent cleaning results. Insufficient pressure or a knife blade that is either dull or even serrated permits the production of all other grades even to the coarsest strips.

The fresh fiber as it comes from the stripping knife is so saturated with plant juices that even hand pressure is suffi-

cient to expel them, and all of the chemical constituents that they contain consequently dry into the fiber during the drying process that follows. This drying process, as will be shown later, is of the utmost importance to the future strength and durability of the fiber, yet no drying sheds are ever provided, and the fiber being dried in the open is subjected to all the vicissitudes of a tropical wet climate and the drying consequently requires anywhere from two hours to two weeks.

The freshly stripped fiber is bright in luster, high in color, very elastic, and somewhat weak. Quick and thorough drying accomplishes the triple purpose of making permanent the luster; of keeping the color from darkening, except very slowly; and of hardening and toughening the fiber strands, together with the more or less pulpy substances surrounding them, and thereby reducing the elasticity to normal. The fiber, promptly and and well dried, is then in its best possible physical condition to perform its alloted commercial functions, which are to maintain its tensile strength, color, and resistance to wear for a reasonably long time.

Abacá fiber, as has been shown, is vegetable in its origin and chemically is composed to a very large extent of cellulose, in and with which is bound up a rather large number of chemical substances, both organic and inorganic, that in their entirety constitute the true fiber body, and through their varying amounts and combinations give rise to the many grades now recognized commercially. To determine how, when, and why abacá fiber became weak and discolored—that is, became damaged and perished, was the object of this investigation.

EXPERIMENTAL

On visiting the warehouses where large quantities of fresh abacá fiber were being received and classified daily it was obvious that the deterioration evidenced by some of the fiber had taken place in the provinces where the fiber was produced. On visiting the provinces and studying the methods of fiber production it was equally certain that damaged fiber was also coming into the provincial warehouses accompanying the strong fiber in varying amounts and showing different degrees of deterioration. Allowing for the relatively short time factor involved the damage was apparently caused by either chemicals or fermentation, and in as much as all damaged fiber was less valuable than undamaged fiber it seemed only reasonable to ascribe the

deterioration to nothing deliberately brought about by anyone but to incidental commercial conditions of fiber production as practiced, hence the use of chemicals was impossible, and therefore the presence and agency of active ferments in causing fiber deterioration became a working hypothesis.

A study of the fiber-stripping process as carried out in the abacá districts shows that some 85 per cent of the abacá plant, felled for stripping, after the fibrous layers, or tuxies, have been removed, is left on the ground around the growing and immature plants, where it promptly ferments and decays, and in the course of a few months is again absorbed by the soil as new plant food. Therefore, the growing plants are always surrounded by fermenting material, and to demonstrate the presence of the active agents of fermentation, their method of action, and the results brought about by them was the next step.

The reduction of vegetable matter containing, as in the case of abacá, cellulose, carbohydrates, proteins, woody matter, and inorganic salts, to available plant food is chiefly brought about by the microörganisms called bacteria, often assisted by fungi, commonly known as mold. The differences between the bacteria and the fungi, both causing deterioration and decay, are many and well marked. The fungi, generally speaking, are plantlike in structure, being supported on appendages resembling roots, and reproducing by means of spores very rapidly, though their growth and multiplication are measured by days rather than by hours and minutes. Bacteria, on the other hand, are a much simpler form of vegetable life, in that they have no rootlike supports, many kinds in fact are even motile and reproduce by division, each new entity redividing as often as once every ten or fifteen minutes under favorable conditions, such as are furnished by the pulpy residual trunks from which the fiber layers are stripped and even by the freshly stripped, juice-saturated fibers themselves.

So fast working and complete is this bacterial action in all countries producing hard fibers, to which the many varieties of hemp belong, that it is made use of to free the fiber bundles from the pulpy, cellular matter surrounding them. In the Philippines the entire sisil and maguey fiber crop is produced by this fermentive process, or "retting" as it is called, the vital points of which are the following:

Great care in allowing the process to progress only far enough to soften and disintegrate the extraneous vegetable matter without acting

on the fibers themselves, for though the fiber is quite resistant and the last to soften and disintegrate, it will do so eventually.

Careful cleaning and washing of the retted fibers to free them of the still clinging cellular matter and especially to eliminate the acids formed through fermentive action, as these acids are recognized everywhere as the great destroyer of all kinds of vegetable fiber.

Careful thorough drying of the retted fiber after the washing is completed in order to kill all bacterial and other microörganisms still clinging in countless numbers to the wet fiber. Long and costly experience has shown that this is the cheapest and best way of ensuring long life and durability to the retted fiber.

In as much as the commercial methods of abacá production as now practiced made it not only possible but very probable that the above facts had a direct bearing on the causation and control of weak fiber, the relatively slower-acting and more-localized fungi were left for later investigations and attention was concentrated on the bacteria, the results of whose marvelous activity were in evidence everywhere in the abacá fields.

THE PRESENCE, THE CHARACTERISTICS, AND THE EFFECTS OF BACTERIA CAUSING ABACÁ FERMENTATION

COMPARATIVE BACTERIAL COUNTS FROM THE YOUNG LEAF, THE OLD LEAF, AND THE DRY STEM [1] OF ABACÁ

Twenty-four abacá plants, divided into two sets of twelve each, were used for experimentation. The two sets were located some distance apart, so that the local conditions of each would be different.

Round pieces, about 8 millimeters in diameter, of the young leaf, the old leaf, and the dry stem were punched out by means of a sterile cork borer and well washed in equal amounts (about 10 cubic centimeters) of sterile water, from which 0.5 cubic centimeter was planted on plain agar for colony count. The reading was made after forty-eight hours with the results recorded in Table 1.

The experiment shows in a more or less uniform manner that bacteria exist in innumerable amount in the dry stem and that more bacteria are found in the young leaf than in the old leaf. Expressing the result graphically we have—

Dry stem > Young leaf > Old leaf >.

[1] The dry stems referred to in these experiments were those that are always found clinging to the outside of the trunk after the leaf itself has died and fallen. When the plant is cut down for stripping the dried portion is discarded.

TABLE 1.—*Bacterial colonies on young leaf, old leaf, and dry stem of abacá.*

	Colonies.			Colonies.	
	On plate.	Per cubic centimeter.		On plate.	Per cubic centimeter.
I. Young leaf	763	1,526	1. Young leaf	360	720
Old leaf	7	14	Old leaf	3	6
Dry stem	954	1,808	Dry stem	(a)	(a)
II. Young leaf	22	44	2. Young leaf	4	8
Old leaf	5	10	Old leaf	14	28
Dry stem	163	326	Dry stem	(a)	(a)
III. Young leaf	2	4	3. Young leaf	5	10
Old leaf	6	12	Old leaf	5	10
Dry stem	38	76	Dry stem	(a)	(a)
IV. Young leaf	60	120	4. Young leaf	954	1,808
Old leaf	3	6	Old leaf	14	28
Dry stem	4,579	9,158	Dry stem	(a)	(a)
V. Young leaf	2	4	5. Young leaf	4	8
Old leaf	0	0	Old leaf	35	70
Dry stem	11,448	22,896	Dry stem	(a)	(a)
VI. Young leaf	5	10	6. Young leaf	20	40
Old leaf	0	0	Old leaf	5	10
Dry stem	826	1,652	Dry stem	(a)	(a)

[a] Innumerable.

IDENTIFICATION OF THE BACTERIAL FLORA FOUND ON THE GROWING PLANT

Experiments to isolate and identify the different kinds of bacteria growing on plain agar were made as follows:

From the fermentation tubes containing pieces of the young leaf, old leaf, and dry stem, after twenty-four hours incubation, a loopful was taken and planted on plain agar plate. The latter was incubated for forty-eight hours. At the end of that time, different looking colonies were fished out and planted on plain agar slant. The identification of the different bacteria was worked out by their morphology, staining characteristics, sugar reactions, and other biological characteristics. The unidentified bacteria were classified according to Bergey's Manual of Determinative Bacteriology.

The following bacteria isolated were readily identified:

Staphylococcus aureus.—Coccus in graplike clusters producing a golden-yellow growth on agar.

Staphylococcus citreus.—Coccus in grapelike clusters producing a lighter lemon-yellow growth on agar.

Staphylococcus albus.—Coccus in grapelike cluster arrangement producing a white growth. The staphylococci are non-gas producers but attack carbohydrates forming acid in dextrose, lactose, and saccharose.

Bacillus prodigiosus.—Motile rod-shaped bacillus producing a red pigment on agar. It produces a small amount of carbon dioxide (CO_2) gas in dextrose broth.

There were other chromogenic bacilli isolated which needed further tests for their identification. All of them belong to the genus *Flavebacterium,* possessing feeble power of attacking carbohydrates. Some of them present sugar reactions identical with the pineapple brown rot. (See Table 2.)

All the bacteria mentioned in Table 2 belong to the genus *Flavobacterium,* defined as rod-shaped bacteria of medium size without endospores forming a yellow to orange pigment on culture media. Characterized by feeble powers of attacking carbohydrates, occasionally forming acid from dextrose but no gas. Motile or nonmotile and generally Gram negative. I–OL_1 and III–YL_1 have the same sugar reactions, identical with those of the pineapple brown rot.

There were also nonchromogenic and nonspore-producing bacteria found in the young and the old leaves and the dry stem of abacá. *Bacillus lactis aerogenes,* a powerful gas-producing bacterium, was the principal one; it was numerous especially in the dry stem and the young leaf. (See Table 3.)

The first set, IV–DS_3, has practically the same biological characteristics as *B. dysenteriae* Shiga except that it does not agglutinate with antidysenteric serum and the growth on agar is more abundant than that of *B. dysenteriae.* It should, therefore, belong to the genus *Eberthella,* the members of which are motile or nonmotile, Gram-negative rods growing well on artificial media, attacking a number of carbohydrates; acid being formed in dextrose but no gas, and do not form acetyl methyl carbinol.

The second set, I–DS_1, is a Gram-negative rod growing well on artificial media, attacking many carbohydrates, forming acid and gas in dextrose, and producing acetyl methyl carbinol. The sugar reaction and other biological characteristics exactly correspond to those of *B. lactis aerogenes.*

The third set, I–DS_2, is similar to the preceding in its biological characteristics except that it produces acid and gas in dulcite and the growth on agar is scanty. It therefore belongs with the preceding to the genus *Aerobacter.*

The last set, II–DS_3, is a Gram-negative rod, very motile, does not form acetyl methyl carbinol, and does not ferment any of the carbohydrates. It apparently belongs to the genus *Alcaligenes* and is possibly identical with *B. alcaligenes bronchisepticus,* which does not reduce nitrates and does not liquefy gelatin.

TABLE 2.—*Chromogenic bacteria on the young leaves, the old leaves, and the dry skin (genus Flavobacterium).*

[YL, young leaf; OL, old leaf; DS, dry stem.]

Kind.	Morphology.	Slant agar.	Gram.	Motility.	Nitrate reduction.	Acetyl methyl carbinol.	Indol.	Blood serum.	Gelatin liquefaction.	Litmus milk.	Glucose.
II–DS_4 5–OL_2	Coccobacillus; occurring singly and in irregular clumps.	Abundant growth; light brown; moist and smooth.	—	—	—	—	—	—	—	[b]	—
4–DS_2	Short slender rods; arranged singly.	Yellowish brown; flat with finely serrated margin; surface smooth and moist.	—	—	+ +	—	—	—	—	[b]	+
IV–DS_2	Medium-sized rods resembling *B. typhosus*; arranged singly and in irregular clumps.	Light cream; slightly raised, with undulate margin.	—	—	—	—	—	[a] +	+ +	[c]	—
6–DS_1 IV–DS_4 V–OL_2	Short plump rods; arranged singly and in clumps.	Lemon yellow; filiform growth; smooth and moist.	—	—	—	—	—	—	—	[b]	—
II–YL_6 II–DS_1	Short plump rods, some coccoid; arranged in short chains and some in clumps.	Bright orange; granular center.	—	—	—	—	—	—	∓	[b]	—
I–OL_1 III–YL_1	Short plump rods, others appear as coccobacilli; arranged singly.	Light brown; abundant, moist, and smooth.	—	—	—	—	—	—	—	[b]	+

[a] Liquified. [b] No change. [c] Color reduced to white.

Kind.	Morphology.	Slant agar.	Mannite.	Maltose.	Xylose.	Dulcite.	Lactose.	Saccharose.	Salicin.	Dextrin.	Russell.
II–DS_4 ---------- 5–OL_2 ---------- 4–DS_2 ----------	Coccobacillus; occurring singly and in irregular clumps. Short slender rods; arranged singly.	Abundant growth; light brown; moist and smooth. Yellowish brown; flat with finely serrated margin; surface smooth and moist.	—	—	—	—	—	—	—	—	— —
			—	+	—	—	—	—	—	—	— —
IV–DS_2 ----------	Medium-sized rods resembling *B. typhosus*; arranged singly and in irregular clumps.	Light cream; slightly raised, with undulate margin.	—	—	—	—	—	—	—	—	— —
6–DS_1 ---------- IV–DS_4 ---------- V–OL_2 ----------	Short plump rods; arranged singly and in clumps.	Lemon yellow; filiform growth; smooth and moist.	—	—	—	—	—	—	—	—	— —
II–YL_6 ---------- II–DS_1 ----------	Short plump rods, some coccoid; arranged in short chains and some in clumps.	Bright orange; granular center.	—	—	—	—	—	—	—	—	— —
I–OL_1 ---------- III–YL_1 ----------	Short plump rods, others appear as coccobacilli; arranged singly.	Light brown; abundant, moist, and smooth.	+	+	+	—	—	+	—	—	+ +

TABLE 3.—*Nonchromogenic and nonspore-producing bacteria found in the young leaves, the old leaves, and the dry stem of abacá.*

	Morphology.	Slant agar.	Gram.	Motility.	Nitrate reduction.	Acetyl methyl carbinol.	Indol.	Blood serum.	Gelatin liquefaction.	Litmus milk.	Russell.
IV–DS$_3$	Coccobacillus; arranged singly and in irregular clumps; no agglutination to antidysenteric serum.	Abundant growth; moist, white, and opaque; undulating margin.	—	—	—	—	—	—	—	(a)	±
I–YL$_2$											
III–YL$_3$											
I–YL$_1$											
3–YL$_3$											
6–YL$_1$											
I–DS$_1$	Coccobacillus; arranged singly and in irregular clumps.	Abundant growth; moist, white, and opaque.	—	—	+ +	+	—	—	—	b + +	+
5–DS$_1$											
I–YL$_3$											
I–DS$_2$	Medium-sized rods resembling *B. typhosus*.	Scanty growth; filiform, smooth, moist, and grayish white; translucent.	—	—	+ +	+	—	—	—	b + +	+ +
V–DS$_3$											
2–YL$_1$											
II–DS$_3$	Medium-sized rods; arranged singly and in irregular clumps.	Grayish white; translucent; flat growth; smooth and moist surface.	—	+ +	—	—	—	—	—	(a)	— —
V–DS$_2$											
5–OL$_1$											

[a] No change.

[b] Coagulation.

[c] Turning green.

	Morphology.	Slant agar.	Adonite.	Glucose.	Mannite.	Maltose.	Xylose.	Dulcite.	Lactose.	Sucrose.	Salicin.	Dextrin.
IV–DS$_3$	Coccobacillus; arranged singly and in irregular clumps; no agglutination to antidysenteric serum.	Abundant growth; moist, white, and opaque; undulating margin.	—	+	—	—	—	—	—	—	—	—
I–YL$_2$												
III–YL$_2$												
I–YL$_1$												
3–YL$_6$												
6–YL$_1$												
I–DS$_1$	Coccobacillus; arranged singly and in irregular clumps.	Abundant growth; moist, white, and opaque.	+	+	+	+	+	—	+	+	+	+
5–DS$_1$												
I–YL$_3$												
I–DS$_2$	Medium-sized rods resembling *B. typhosus*.	Scanty growth; filiform, smooth, moist, and grayish white; translucent.	+	+	+	+	+	+	+	+	+	+
V–DS$_3$												
2–YL$_1$												
II–DS$_3$	Medium-sized rods arranged singly and in irregular clumps.	Grayish white; translucent; flat growth; smooth and moist surface.	—	—	—	—	—	—	—	—	—	—
V–DS$_2$												
5–OL$_1$												

Spore-bearing bacteria belonging to the *subtilis* group were also present. They are especially numerous in the dry stem and the old leaf. They do not produce acid or gas.

GAS-PRODUCING BACTERIA AND THEIR DISTRIBUTION ON THE GROWING PLANT

Taking advantage of the well-known characteristic of *Bacillus lactis aerogenes* and allied species to produce gas in media containing carbohydrates, their relative distribution on the various parts of the growing plant was determined by this means.

Pieces of the young leaf, the old leaf, and the dry stem were placed in separate fermentation tubes. These specimens were taken from the twelve plants used in the preceding experiment. The amount of gas produced was noted after twenty-four hours, seventy-two hours, and a week of incubation at 37° C. The fermentation tubes contained nutrient bouillon with 1 per cent lactose titrated to +1 reaction. Table 4 shows the results of the experiment.

TABLE 4.—*Gas produced in fermentation tubes after various periods.*

FIRST SET. DECEMBER 24, 1926.

Plant.	Young leaf.			Old leaf.			Dry stem.		
	24 hours.	72 hours.	1 week.	24 hours.	72 hours.	1 week.	24 hours.	72 hours.	1 week.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
I	6	33	38	27	85	85	27	42	50
II	13	52	52	19	32	60	26	62	78
III	13	58	58	19	32	65	46	77	80
IV	21	85	85	40	42	55	17	42	46
V	8	31	33	17	46	85	19	62	80
VI	3	28	32	21	46	46	23	44	68
SECOND SET. JANUARY 17, 1927.									
1	0	26	32	17	56	77	33	73	77
2	17	56	58	9	17	19	21	65	77
3	18	62	70	20	40	43	32	40	43
4	11	55	62	12	17	62	0	32	65
5	6	29	36	0	65	65	29	49	58
6	0	8	12	13	29	29	58	78	80
Average	9.6	43.5	47.3	17.8	42.2	57.5	27.5	55.5	66.8

The results show that gas is produced by bacteria found in the dry stem, the old leaf, and the young leaf and that the gas produced by the dry stem is more than that from the old

leaf, and that from the old leaf is more than from the young leaf. Expressing the results graphically, we have after twenty-four hours and one week incubation—

$$\text{Young leaf} + < \text{Old leaf} + < \text{Dry stem} +.$$

After seventy-two hours incubation the result is irregular. These results appear contradictory to the first experiment where we had—

$$\text{Dry stem} > \text{Young leaf} > \text{Old leaf}.$$

The foregoing, however, referred to quantity numbers of bacteria, while in the latter the amount of gas is determined by the amount of fermentable substance present as well as by the number of bacteria, and these two factors modify the results as shown.

BACTERIAL CONTAMINATION OF FIBER THROUGH THE STRIPPING PROCESS

The abacá field having shown itself to be a hot bed of bacterial action it necessarily follows that in as much as no attempts are ever made to protect the abacá fiber from contamination during the stripping process, all the fiber would probably be more or less heavily infected by bacteria.

To get at the relative amount of infection suffered by the fiber coming from the various layers of the stalk, that is, outside, middle, and inner layers, the following objectives were planned and carried out:

RELATIVE CONTAMINATION AS MEASURED BY GAS PRODUCTION

During the process of stripping, about equal pieces of all the important parts were taken with all aseptic precautions and placed in fermentation tubes containing nutrient bouillon with 1 per cent lactose titrated to + reaction. The gas produced was measured after twenty-four and forty-eight hours incubation at 37° C. with the results recorded in Table 5.

TABLE 5.—*Gas production after incubation in fermentation tubes for twenty-four and forty-eight hours.*

	24 hours.	48 hours.		24 hours.	48 hours.
	P. ct.	*P. ct.*		*P. ct.*	*P. ct.*
1. Young leaf	1.5	33	7. Outer tuxie	0	7
2. Old leaf	11.5	24	8. Middle tuxie	0	0
3. Dry stem	16.3	72	9. Inner tuxie	0	0
4. Young skin	3	3	10. Outer fiber	6	72
5. Sap	0	0	11. Middle fiber	2	35
6. Heart of stem	0	0	12. Inner fiber	1	56

Expressing the results graphically after twenty-four hours incubation in the raw material—

Dry stem + > Old leaf + > Young skin + >Young leaf +.

The heart of stem, sap, outer tuxie, middle tuxie, and inner tuxie remain without gas even after forty-eight hours except the outer tuxie.

In the case of the finished fiber—

Outer fiber + > Middle fiber + > Inner fiber + .

The experiment shows that while the gas-producing bacteria are ever present in the outside layers of the stalk, inner tuxies from which the finer fibers are stripped are comparatively free from them. In the process of stripping, however, all the finished fibers become infected with the gas-producing bacteria.

COMPARATIVE BACTERIAL COUNTS FROM INFECTED PARTS

Equal pieces of the different parts of abacá were well washed, each in 10 cubic centimeters of sterile water. From each of the waters 0.5 cubic centimeter was planted on plain agar for colony count after forty-eight hours incubation.

TABLE 6.—*Colonies on plain agar after incubation for forty-eight hours.*

Portion.	Colonies—		Portion.	Colonies—	
	On plate.	Per cubic centimeter.		On plate.	Per cubic centimeter.
1. Young leaf	10	20	7. Outer tuxie	14	28
2. Old leaf	36	72	8. Middle tuxie	4	8
3. Dry stem	[a]	[a]	9. Inner tuxie	3	6
4. Inner stem	43	86	10. Outer fiber	168	336
5. Sap	72	144	11. Middle fiber	6	12
6. Heart of trunk	1	2	12. Inner fiber	3	6

[a] Innumerable.

Expressed graphically—

Dry stem > Inner stem > Old leaf > Young leaf;

Outer tuxie > Middle tuxie > Inner tuxie > Heart of trunk;

Outer fiber > Middle fiber > Inner fiber;

Sap > Inner stem.

IDENTIFICATION OF THE PRINCIPAL KINDS OF BACTERIA PRESENT

Attempts to isolate the principal kinds of bacteria growing in the fermentation tubes showing gas after forty-eight hours incubation were made, using Teague-medium plates. The principal and most abundant kind of colonies were fished out and planted on slant agar. Subsequent identification was under-

taken with the results recorded in Table 7. The biological characteristics are recorded in Table 8.

TABLE 7.—*Identification of bacteria.*

Isolated from—	Kind.	Appearance on Teague plate.
Young leaf Dry stem Outer tuxie Outer fiber	1. *Bacillus lactis aerogenes*	Large colonies; rosy red, round, smooth, much raised, and very moist.
Middle fiber Inner fiber	2. *Bacillus prodigiosus*	Dark purple, moist, round colonies.
Old leaf	1. *Subtilis* group (b) *Bacillus megaterium.*	Small round colonies; dark purple with refracted light and a greenish dry metallic luster resembling *B. coli.*
	2. *Bacillus bronchisepticus*	Small round entire colonies, grayish white; moist and smooth surface.
Inner stem	1. Eberth group	Small grayish white colonies; transparent and flat; serrated margin.
	2. Identical with pineapple brown rot bacillus.	Perfectly round colonies; much raised; moist; brownish with reflected light; with refracted light the center is dark purple and the periphery grayish white.

THE EFFECT OF DRYING FRESH FIBER ON ITS NORMAL BACTERIAL CONTAMINATION

Observations made in the field and supported by the foregoing experiments appear to show that all commercial abacá fiber produced by present methods of stripping is more or less heavily contaminated with bacteria, and that the juice and soluble substances accompanying the fiber furnish the media for their prompt and vigorous growth. Drying, or the process in commercial fiber production that follows the stripping (where the bacterial contamination takes place), is therefore of great importance, as it determines whether the bacteria shall live and cause damage or die and become harmless.

The following experiments were undertaken to show the various effects of thorough and prompt drying on the bacteria normally present, so to speak, on the fiber. Attention is called to the two phases that developed as the experiment progressed. The first was the increasing mortality as drying progressed up to the seventh day. On that day the second phase appeared, due to the fact that rains caused a sudden increase in relative humidity, the fiber reabsorbed moisture and the remaining bacteria not only lived but promptly began their multiplication by division.

TABLE 8.—*Biological characteristics of bacteria.*

	Colonies on Teague plates.	Slant agar.	Morphology.	Gram.	Motility.	Litmus milk.	Gelatin liquefaction.
Young leaf I	Exuberant growth. Large round colonies. Much raised with entire margin. Rosy-red color; smooth and very moist.	Abundant, opaque, white, moist, smooth surface and spreading.	Slender rods about the size *B. typhosus* occurring singly and irregular clusters.	—	—	Acidity with coagulation.	—
Young leaf II	Dark purple, moist, round colonies; entire margin.	Blood-red; growth moist and spreading.	Short slender rods occurring singly.	—	+	Acidity present.	[a] +
Old leaf I	Small round and flat colonies with a dark purple color. Surface has greenish metallic luster like *B. coli*.	Opaque cream color; growth moist; slightly granular surface.	Thick bacillus with central spores like *B. subtilis* arranged in short chains. After 3 days they appear as globular bodies without any stain and arranged singly and in short chains.	+	[b] +	Acidity very slight.	+
Old leaf II	Small round colonies; slightly raised and entire margin; grayish white in color; moist and smooth surface.	Filiform growth, grayish white, moist, glistening surface. Margin smooth.	Fine short and slender bacilli (rods) occurring singly and irregular clusters.	—	++	No change	—
Inner stem I	Small colonies; flat with serrated margin, transparent and grayish white in color.	Flat but spreading grayish white growth, transparent and serrated margin.	Short slender rods occurring singly and in irregular clumps.	—	+++	do	—
Inner stem II	Large colonies; round entire margin; much raised, moist surface; brownish in color with reflected light; dark purple center, grayish white periphery with refracted light.	Abundant brownish growth, moist, smooth surface and margin.	Short fine rods occurring singly and irregular clumps.	—	+	Acidity slight	—

[a] Red surface.

[b] Slow wormlike motion.

[c] Turning green.

	Blood serum.	Indol.	Nitrate reduction.	Acetyl methyl carbinol fast.	Russell.	Glucose.	Mannite.	Maltose.	Xylose.	Dulcite.	Lactose.	Sucrose.	Salicin.	Dextrin.	Adonite.
Young leaf I	−	−	+	+	+	+	+	+	+	−	+	+	+	+	+
Young leaf II	−	−	+	−	+	+	+	S	−	−	−	+	−	−	−
Old leaf I	−	−	−	−	S	+	S	−	−	−	−	+	−	−	−
Old leaf II	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
Inner stem I	−	−	+	−	+	+	−	−	−	−	−	−	−	−	−
Inner stem II	−	−	+	+	+	+	+	+	+	−	−	+	−	−	−

The freshly stripped fiber was classified into outer, middle, and inner fiber, derived from outer, middle, and inner tuxies, respectively. These were hung up in the room with free air access. About equal portions of each were cut each day and suspended and well washed in 10 cubic centimeters of sterile water; then relative bacterial counts were made on plain agar after forty-eight hours incubation. The results are recorded in Table 9.

From the above experiment we may draw the following conclusions:

That as drying progressed the bacterial contamination was gradually reduced, reaching the minimum after seven days hanging in the room. After the first day the fiber samples were "commercially dry," but it is very evident that this is not enough to reduce the bacterial count sufficiently and that longer drying or direct sunlight is highly desirable.

That the fibers, both the freshly made as well as the commercially dry, are invariably contaminated with bacteria capable of producing fermentation as soon as moisture is sufficiently increased.

That the outer fibers contain the greatest and the inner fibers contain the least number of bacteria.

THE EFFECT OF FERMENTATION BY ABACÁ BACTERIA ON FIBER IN VARIOUS STAGES OF DRYING AND STORAGE

THE EFFECT OF FERMENTATION ON FRESHLY STRIPPED FIBER

Hanks of freshly stripped, mature fiber of mixed grade were selected, the moisture contents being arranged as follows:

1. Was "wringing wet" or just as it came from the stripping knife, and contained at least 50 per cent juice.
2. Had been partially dried so that it contained some 20 per cent juice.
3. Was part of No. 2 but had been moistened with clean river water so as to contain about 40 per cent moisture.

These hanks were carefully wrapped in fresh abacá leaves to prevent outside soiling, then covered with the waste material discarded by the stripping knives and left there. This waste material, made up of discarded fiber, pulpy material, and plant juices, was fermenting so rapidly that it was distinctly warm. The results of the fermentation on these fibers induced through the ordinary infection received from stripping, handling,

TABLE 9.—*Experiments to show the effects of thorough and prompt drying.*

Day.	Portion.	Gas after 24 hours.	Gas after 48 hours.	Relative bacterial count per cubic centimeter.
		Per cent.	*Per cent.*	
First	Outer fiber	6	72	336
	Middle fiber	2	35	12
	Inner fiber	1	56	6
Second	Outer fiber	1.5	19.2	10
	Middle fiber	0	0	2
	Inner fiber	0	23	8
Third	Outer fiber	0	16	4
	Middle fiber	0	4	0
	Inner fiber	0	4	4
Fourth	Outer fiber	3	12.3	8
	Middle fiber	0	0	2
	Inner fiber	0	6	2
Fifth	Outer fiber	0	3.8	6
	Middle fiber	0	0	2
	Inner fiber	0	0	2
Sixth	Outer fiber	0	3	4
	Middle fiber	0	0	2
	Inner fiber	0	0	2
Seventh	Outer fiber	0	0.8	2
	Middle fiber	0	0	0
	Inner fiber	0	0	0
Eighth	Outer fiber	0	0	2
	Middle fiber	0.8	9	2
	Inner fiber	0	0	0
Ninth	Outer fiber	0	20.7	4
	Middle fiber	0	0	0
	Inner fiber	0	7.6	4
Tenth	Outer fiber	0	0	4
	Middle fiber	0	11.5	12
	Inner fiber	0	7.6	2
Eleventh	Outer fiber	0	0	2
	Middle fiber	0	3	4
	Inner fiber	0	0	4
Twelfth	Outer fiber	0	3	12
	Middle fiber	0	7.6	6
	Inner fiber	0	0	2

and wrapping in the abacá leaves could be summed up as follows:

1. After two days it had developed a volatile acid odor that slowly disappeared on exposure to the air. The color of the well-cleaned fiber was almost unchanged, but the strippy parts showed a brownish yellow color that deepened on exposure to the light. The acid contents when titrated had increased three to

four times in amount over the part kept in reserve and promptly dried. The fiber was strong when first removed, but in three months it became so brittle and weak that a large part could be classed as damaged.

2. This was kept six days covered by the waste when unforseen conditions made its removal necessary. It was found to be of good color, only slightly increased in acidity, and in three months only a very small number of fibers showed weakness. The drying, although not complete, had evidently increased its resistance to a marked degree over the undried fiber.

3. When removed, also after six days, this fiber had a good color, but the acid contents were doubled, and after three months a considerable number of fibers, especially the strippy grades, became weak and went down in color.

THE EFFECT OF FERMENTATION ON WET WAREHOUSE FIBER

A warehouse fire in Manila, in which many hundred bales of abacá, both U. S. and U. K. grades, were damaged, made possible the following test: The fire smoldered among the high piles of bales for nearly a week, necessitating flooding them until everything was soaked. The rattan bands of most of the bales were burned so that the bales fell apart, and while much of the surface fiber was burned or charred, most of the inside fiber remained untouched, except that it was water soaked. This fiber was removed from the warehouse by the hank, wet and cold, and thrown into piles outside. A pile some 4 meters high was selected and an iron pipe driven down near the center so the temperature could be taken daily. The temperature outside averaged about 28° C. although sun and rain changed this somewhat. The temperature at the bottom of the pipe began to rise very soon, gained a little every day, and in one week registered 67° C. After that it declined each day, at a slower rate. Unfortunately, the pile had to be broken down at the end of two weeks. The changes in the acidity of the fermenting fiber were also noted, for tests of the fiber when it went to the pile showed it to be low in acidity probably on account of the dissolving action of the water. After fermentation in the pile began in earnest the acidity continued to rise for a week when it was four to five times more than that at the beginning. After that it steadily decreased until the day before the pile was broken down when the fiber withdrawn reacted slightly alkaline. Needless to say most of this fiber after drying was perished, yet considerable was also found that was still strong to hand test-

ing, showing the resistance of certain fibers even to the worst possible conditions.

This increase followed by decrease in acidity and finally the presence of alkalinity is perhaps explained by the well-known fact that ordinary mixed fermentation is acid in character, due to the breaking down first of the more easily decomposed carbohydrates and other bodies that give acid products, but after these have been acted upon, the bacteria attack the nitrogenous matter and form products which ultimately react alkaline, and neutralize the acids first formed.

THE EFFECT OF FERMENTATION ON THE WATER-SOLUBLE CONSTITUENTS OF HIGH- AND LOW-GRADE FIBER

To throw additional light on the apparently complicated bacterial action above described, experiments were tried on a small scale with the soluble constituents only, of several grades of fiber, to see if they also increased and decreased in acidity as fermentation progressed.

TABLE 10.—*The total acidity of 10 grams of fiber of each grade, expressed in cubic centimeters of alkali used.*

	Sample 1, AA grade.	Sample 2, L_1 grade.	Sample 3, J_1 grade.
	cc.	*cc.*	*cc.*
Unfermented	1.00	6.50	0.50
First day	2.50	6.00	0.50
Second day	2.25	6.25	
Third day	1.50	4.50	1.00
Fourth day	1.50	5.50	5.50
Fifth day	1.00	5.00	3.00
Sixth day			2.25
Seventh day	0.75	5.50	2.00
Eighth day			2.00
Ninth day	0.50	5.25	2.00
Fourteenth day	0.40	4.50	1.80

One hundred grams of each sample were cut into small pieces, and in suitable glass containers each was extracted with 2 liters of distilled water for three hours on the water bath. The solutions were then poured off, concentrated at low heat to 500 cubic centimeters, and after sterilization in a pressure autoclave for fifteen minutes at 15 pounds pressure were inoculated with equal amounts of a culture of *Bacillus lactis aerogenes*. Incubation was made at 37° C.

For determination of total acidity aliquot parts of the solutions were titrated with decinormal sodium hydroxide, using phenolphthalein as indicator. The figures given in Table 10

represent the total acidity of 10 grams of the fiber of each grade expressed in cubic centimeters of alkali used.

While the rise and fall in the total acidity of the water-soluble constituents of the fiber during fermentation appeared to take place in a manner quite similar to that noted in experiment B, the solutions always remained acid as long as the experiment continued, from which it may be inferred that the bacteria subsequently attacked the insoluble constituents of abacá after the soluble ones had been consumed and this secondary attack gave rise to alkaline products of fermentation.

THE EFFECT OF FERMENTATION ON BALED FIBER

For this purpose ten bales of recently received Bicol fiber, consisting of two bales each of grades F, I, J^1, J^2, and L_1, were opened two by two, the contents thoroughly mixed and then divided again into piles of one bale each, each grade by itself. The moisture content of each bale was determined in the laboratory and enough tap water was sprinkled on one pile of each grade to bring the moisture content up to approximately 20 per cent. The fiber was then all rebaled and stored together where the air circulated freely in a clean dry warehouse during the rainy months of July, August, and September. An iron pipe was so arranged in each bale during the bailing that the temperature in the center of each bale could be taken daily. It was found in the dry bales that no rise of temperature took place or at most one degree in three bales, yet this rise stayed constant in some bales for two weeks when it again became normal. The wet bales, especially the three lower grades, rose from 3 to 4° C., and after continuing that way for a week gradually subsided to normal at the end of the first month. The heat of fermentation by that time probably only equalled the conductivity of the fiber itself as in the case of the dry bales.

On reweighing, previous to inspection, it was found that the dry bales had gained, on an average, 5 kilograms, while the wet bales had lost 3.5 kilograms. The two bales of each grade were opened at the same time and again graded by the same expert that had selected the fiber in the beginning. Summarizing the results, the important changes that had taken place were the following:

The odor of all dry bales was good—that of the wet bales in every case musty or moldy and in the J^1 and L_1 bales was disagreeably sour also. The color of all dry bales was off slightly on yellow or down somewhat for the L_1. The wet bales were off 12.5 to 25 per cent for the higher grades while the lower grades were much too badly off.

The tensile strength by hand testing showed F dry to be unchanged and I dry was still good, but the rest had all gone down, the worst one, L wet, being 80 per cent weak and the worst of the dry was J ^{1}, which was almost half weak.

The microscopical examination of the fibers disclosed the fact that all, with the exception of the F bales and the I dry, were infected with active bacteria as well as fungi.

In acidity the high grades, both wet and dry, had increased but little, while the lower grades had all increased—the wet ones more than the dry, the worst being L wet, which gained four and one-half times.

THE EFFECT OF FERMENTATION ON THE TENSILE STRENGTH OF FIBER

The fiber from two mature abacá plants was carefully mixed so as to be uniform; it was then divided into five portions, each being enough to fill a large Mason jar. One portion was air dried at once, while the rest were sterilized in a pressure autoclave in the tightly closed Mason jar for fifteen minutes at 15 pounds pressure. After cooling they were infected, one with *B. lactis aerogenes,* and one with a spore-bearing air-borne variety of bacterium very prevalent in the abacá fields. One of the two remaining full jars was dried at once, while the other was placed unopened in the incubator with the infected jars and all three were incubated for six days.

After drying, examining, and testing at the end of six days the results recorded in Table 11 were obtained.

TABLE 11.—*Strength and condition of fiber at the end of six days.*

Sample No.	Tensile strength per gram meter.	Color.	Remarks.
	Kilos.		
1	49.36	Regular for J_1 grade	The freshly stripped portion dried at once.
2	49.70	Regular for J_1 grade	Portion sterilized and then dried.
3	48.91	Slightly down	Portion sterilized and incubated, then dried.
4	42.25	Reddish brown; down to Le	Portion infected with *B. lactis aerogenes.*
5	38.32	do	Portion infected with spore-bearing air-borne bacteria.

The tensile strength of the first three samples is probably close enough to be within the limit of error of the experiment, while that of the fourth and the fifth is shown to be decidedly lowered.

PROGRESSIVE LOSS OF TENSILE STRENGTH CAUSED BY THE PRODUCTS OF FERMENTATION

A small hank of perished L fiber was selected, which showed by chemical and microscopical examination that it had gone down in color and tensile strength through intensive bacterial action followed by mold action, and had an acidity some seven times that of normal fiber. It was extracted with warm distilled water and the acid extract sterilized by boiling. A hank of excellent Samar E fiber was divided into two equal parts and one part was soaked in the above extract until the extract was all absorbed, after which the fiber was carefully dried at room temperature and hung up with the untreated half in a cool, dry place, where they were under the same conditions of storage. Each month these two half hanks were tested in a Louis Schopper fiber tester for tensile strength. In less than four months the acid half hank had lost 17.5 per cent of its original strength and the normal half 5.4 per cent. In six months the acid hank was mostly perished and completely so in less than a year. In the same time the normal hank went down at only the normal rate or a little over 9 per cent.

THE ACIDS OF FERMENTED AND UNFERMENTED FIBER

Pending further investigation no definite statement can be made as to the exact rôle played by bacteria in the destruction of abacá fiber with its attendant loss of tensile strength, lowering of color, luster, etc. From the experiments so far made it appears likely that this deterioration may be ascribed to the direct attack of the bacteria on the water-soluble constituents of the fiber, giving rise to various acid products, which in turn act chemically on the insoluble parts, changing them further into bacterial food.

In the preceding paper [2] it was shown, in the examination of a large number of samples of abacá fibers from different districts that their tensile strength was apparently inversely proportional to their total free acid contents, measured against standard alkali. Many other facts also point to the important rôle played by the free acids found in both the fermented and the unfermented fibers and consequently much time has been given to their study, isolation, and purification.

[2] Sherman and Sherman, this issue, 21–40.

SUMMARY

Due to the custom of all abacá growers in the Philippines some 85 per cent of the semiannual plant growth is cut down in the harvesting of the fiber and allowed to ferment and decay underneath the growing, immature plants.

The immediate locality where all the fiber is recovered and stripped is, therefore, a hot bed of bacterial infection, and all commercial fiber produced is heavily infected with bacteria.

The bacterial flora found on all exposed parts of the growing plant as well as on the produced fiber is diversified, large, and active.

The process of drying, which should immediately follow the stripping of the fiber, has for a direct result the practical sterilization of the fiber so long as it remains dry thereafter.

Failure to dry the fresh fiber promptly and thoroughly, or wetting after once dried, results in fermentation, the immediate effects of which are the production of increased acidity, lowering of tensile strength, change of color, decrease of luster—in other words, all of the phenomena that characterize damaged and perished fiber.

These damaging effects on the fiber appear to be caused by the acid fermentation products of its soluble constituents as well as by direct action of the bacteria on the fiber.

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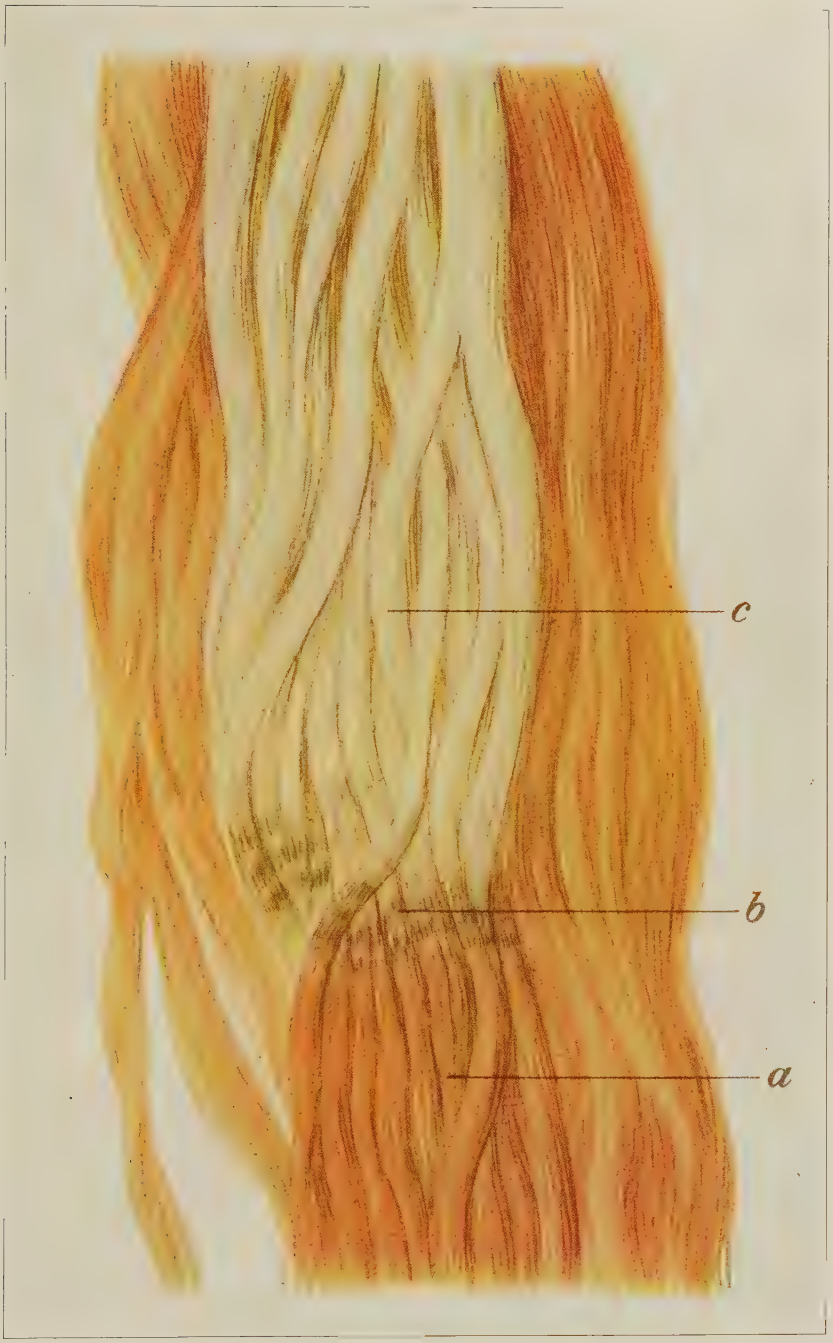
ILLUSTRATION

PLATE 1

A hank of high-grade Davao abacá partially wet while baled, showing change of color due to bacterial action and mold growth; *a*, heaviest bacterial action where fiber was wettest; *b*, black-mold colonies; *c*, still dry, with original color.



A hank of high-grade Davao abacá partially wet while baled, showing change of color due to bacterial action and mold growth.

PLATE 1.

MERCURIC IODIDE IN THE TREATMENT OF EQUINE EPIZOÖTIC LYMPHANGITIS [1]

By R. A. Kelser

Major, Veterinary Corps, United States Army, and member of the United States Army Medical Department Research Board
Manila

ONE PLATE

Epizoötic lymphangitis is a chronic, infectious disease of horses and mules. Rarely the malady also occurs in man. It is caused by a type of yeast, *Blastomyces farciminosus* (*Cryptococcus farciminosus*), and is characterized by a purulent inflammation of the lymphatic vessels and regional lymph nodes of the subcutaneous tissues.

Epizoötic lymphangitis occurs in various parts of Europe, Asia, Africa, and South America. It does not at present exist in the United States. In the Philippine Islands the disease has long been a scourge of the equine population and, in so far as the military establishment is concerned, has proved to be one of the most troublesome conditions with which the Army veterinary service has had to contend.

While an enormous amount of work has been done by various investigators with a view to finding a satisfactory treatment for epizoötic lymphangitis, the results have been quite discouraging. Prompt and thorough surgical interference has given fair results. However, where the involvement is extensive, surgery is not always feasible and at best it results in considerable scarring which, obviously, is undesirable if it can possibly be avoided.

Various chemical agents, such as bichloride of mercury, copper sulphate, phenol, mercury salicylate, iodide of potash, tartar emetic, atoxyl, salvarsan, etc., have been employed in the treatment of the disease. Reports on all of these chemicals are exceedingly variable as regards results obtained.

[1] Published with permission of the Surgeon General, United States Army, who is not responsible for any opinion expressed or conclusions reached herein.

Several years ago the United States Army Medical Department Research Board conducted a rather long series of experiments with a view to finding a satisfactory treatment for epizoötic lymphangitis. This work involved the testing of mercurochrome, gentian violet, various colloidal-silver preparations, gray oil, salvarsan, tartar emetic, potassium iodide, sodium iodide, etc. In some instances we appeared to get results while in others, with the same treatment, failures occurred. It was finally concluded that nothing we had worked with was as satisfactory as prompt and thorough surgical treatment, so the project was dropped.

In October, 1926, Nainsouta(1) published a report in which he indicated that red iodide of mercury, when administered intravenously, was highly effective in the treatment of epizoötic lymphangitis. As a matter of fact he considered that chemical specific for the treatment of the disease. In view of this report we decided to revive our lymphangitis project and test the action of mercuric iodide on some of our cases of epizoötic lymphangitis among Army horses.

In the beginning Nainsouta administered the drug in doses of 0.20 gram twice a week for five weeks. In grave cases he recommended doses of 0.50 gram. He employed 50 cubic centimeters of distilled water for the suspension of each dose of the chemical.

In our work we have found that daily intravenous doses of red iodide of mercury, suspended in 60 cubic centimeters of sterile distilled water, can be safely administered over a period of from seven to ten days. Further, after a lapse of two or three weeks this course of treatment can, if necessary, be repeated without untoward results.

In preparing and administering the chemical we have carried out the following procedure: The 0.50-gram dose of mercuric iodide is very carefully weighed and placed in a sterile Erlenmeyer flask containing 60 cubic centimeters of sterile distilled water. The flask is then shaken vigorously in order to make as fine a suspension of the chemical as possible. Before the drug has a chance to settle the mixture is poured into a Luer type, glass syringe and promptly injected into the jugular vein. Leaving the needle in the vein, the flask and the syringe are quickly washed with about 30 cubic centimeters of sterile physiological saline solution and this is injected, so that the animal gets the full dose of the iodide of mercury.

Great care must be exercised to absolutely insure that none of the chemical is injected into the vessel wall or surrounding tissues. A sterile needle that has not come in contact with the mercuric iodide suspension should be inserted into the jugular vein and a good, steady flow of blood noted before the syringe is attached for the injection. If in the meantime the mercury has settled in the syringe a little shaking just before attaching the syringe to the needle is desirable.

In treating cases of epizoötic lymphangitis it has been our practice to make a small incision in any soft nodules present, evacuate the pus, and then give the animal daily intravenous injections of the red iodide of mercury prepared as above described. In the case of average-weight and heavy horses ten daily injections can be safely given. Series of seven daily injections will ordinarily suffice for smaller horses unless the involvement is extensive in which case the ten injections can be given. The dose for Philippine ponies should not exceed 0.30 gram.

It is desired to emphasize the point that a second series of injections of mercuric iodide should not be commenced until at least two weeks after the completion of the first series.

To the present time nineteen cases of epizoötic lymphangitis have been treated by this method and the results have been highly satisfactory.

After the first few doses of the drug the smaller nodules start to diminish in size and gradually disappear. The larger nodes usually proceed to suppuration, and as soon as they are soft they should be opened. The pus from lesions in animals receiving the mercury treatment soon assumes an entirely different character from that of the untreated case. In the place of the very thick, creamy pus, the discharge from cases well along on the course of mercury treatment usually consists of a fairly fluid, serum-colored material containing small accumulations of pus in the form of white flocculi.

In our experience the course of treatment, in the average case, has extended over a period of not more than two months. In mild cases with minor involvement one course of seven to ten daily doses of the mercuric iodide will usually suffice. With the average case of moderate severity and involvement two courses of the drug with two or three weeks between courses are advisable. In severe cases with extensive involvement a third course may be necessary.

One should not fail to open nodes containing pus, especially the larger ones. This practice certainly aids in reducing the period over which the animal must be treated. A very small incision with a bistoury will prove satisfactory and will not be apt to result in a detectable scar.

The results we have obtained with this treatment are nicely illustrated by our case 7, a horse suffering from a moderately severe case of epizoötic lymphangitis. Plate 1 is from a photograph of the involved region of this animal just before we commenced the mercury treatment. The prominent nodes were incised, the pus evacuated, and daily intravenous injections of 0.50 gram of the mercuric iodide in 60 cubic centimeters of distilled water given over a period of ten days. After a period of two weeks a second course of ten injections was given. The animal started to improve after the fifth or sixth dose of the drug, and progress was continuous up to the end of the second course of treatment when the animal was about normal. However, he was kept under observation for two weeks more, and while probably unnecessary he was given four more daily doses of the mercuric iodide before being sent to work. Treatment of this horse started on September 1, 1927, and he was discharged as cured on October 23, 1927. To the present time there has been no recurrence of the condition.

Lately we have employed an equal part (0.50 gram) of potassium iodide with the mercuric iodide and reduced the amount of water used to 30 cubic centimeters. This gives a solution of the double iodide of mercury and potassium and is more readily administered than the suspension of mercuric iodide alone. This mixture has not been employed over a sufficient period to determine whether or not it is as satisfactory as the mercuric iodide alone. In previous work we have noted that some horses are rather sensitive to potassium iodide when given intravenously, so in some instances it may be desireable to omit the potassium iodide.

I wish to acknowledge my indebtedness to Lieut. Col. Burt English, department veterinarian, Philippine Department, and to Maj. D. B. Leininger, station veterinarian, Fort William McKinley, for their aid in carrying out this work.

REFERENCE

1. NAINSOUTA, R. Action spécifique du biiodure de mercure contra la lymphangite épizootique. Bull. Soc. Pathol. Exot., Paris 19 No. 8 (October, 1926).

ILLUSTRATION

PLATE 1. Involved area of a horse with epizoötic lymphangitis.
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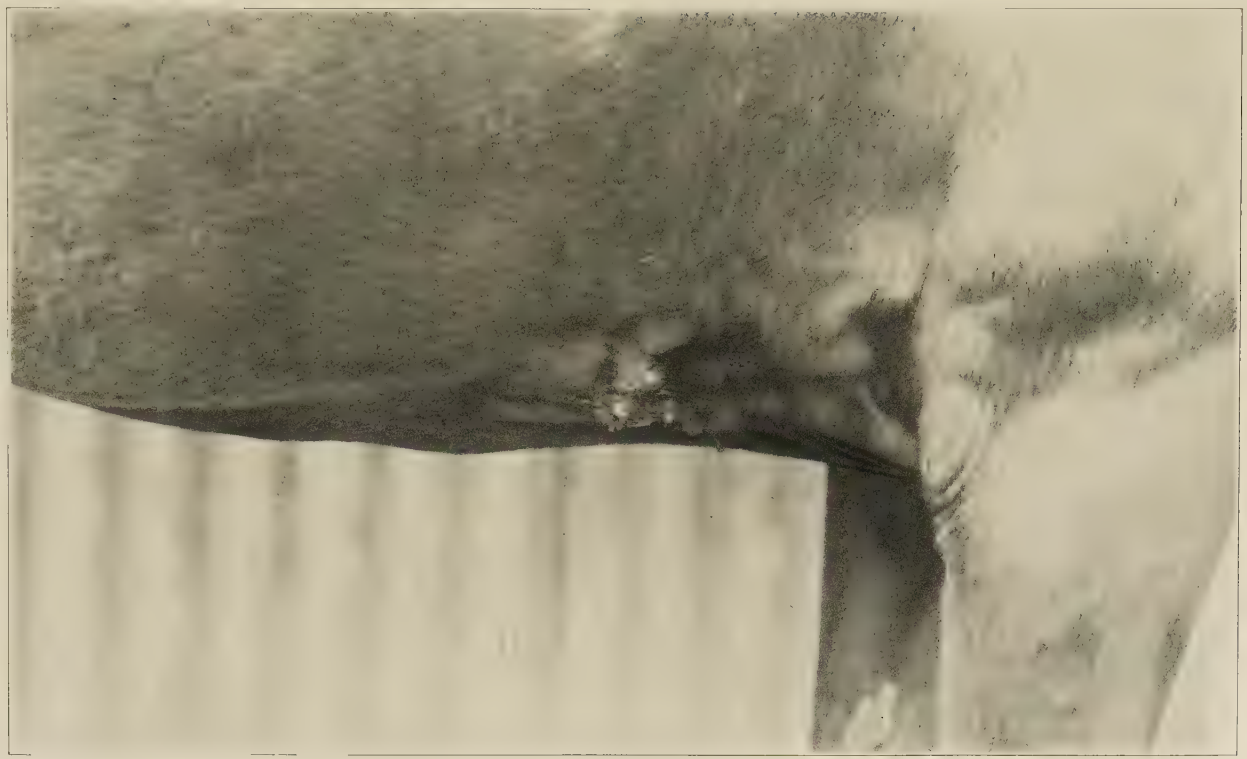


PLATE 1. INVOLVED AREA OF A HORSE WITH EPIZOOTIC LIMPHANGITIS.

NOTES ON PLASMOQUINE (PLASMOCHIN)[1]

By C. M. HASSELMANN and MARGARETE HASSELMANN-KAHLERT

Of Manila, Philippine Islands

ONE TEXT FIGURE

In 1640, Juan del Vego, attending physician to the Countess Anna del Cinchon, took the bark of *Cinchona* species from Ecuador to Europe. The derivation of the word quinine is still under discussion. Probably, this expression does not come from the name of the countess but from the word *knia,*(1) which means "bark" in the language of the old Peruvians. The duplication would signify, as in all primitive languages, only "of special importance;" as, for example, in the case of *tse-tse,* where *tse* in the language of the Zulu-Kafirs means "fly," and *tse-tse,* therefore, means a very important and dangerous fly.

Many attempts have been made to replace this febrifuge by other drugs. In 1820 Pelletien and Caventon isolated quinine from the bark. Quinine synthesis has been attempted many times since 1856 when Perkin, still thinking that quinine had two quinoline rings, succeeded in producing mauvëin, the first coal-tar dye.

It has long been known that quinine acts only upon the malarial schizonts; the sexual forms, especially the crescents in subtertian infection, are not destroyed. Thirty years ago Marchiafava and Bignami(2) said:

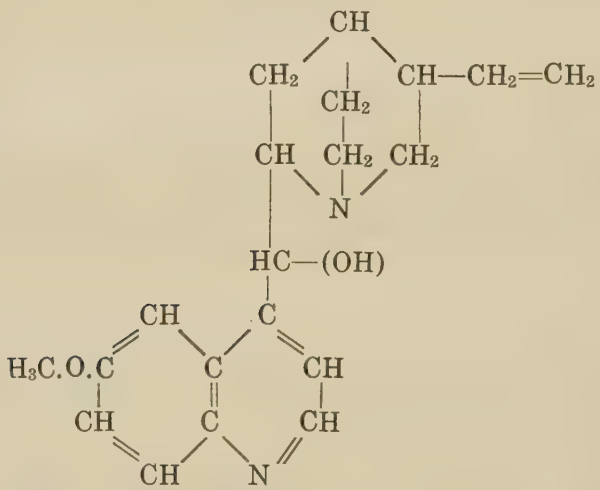
> The salts of quinine, even when given in doses as large as 2 grams a day, do not perceptibly affect the crescent forms of these parasites. Quinine

[1] Plasmoquine was first brought to the Philippines in December, 1926, by one of the authors (C. M. H.) and given to private patients, for both treatment and prophylaxis. These trials were again taken up when, during the summer of 1927, the then representative of the Bayer firm furnished a greater supply of the drug. Through the kindness of Dr. Jacobo Fajardo, director of the Philippine Health Service, and Dr. C. Gavino, director of San Lazaro Hospital, a greater number of malaria cases were treated with plasmoquine in addition to our private patients. Dr. C. Policarpio, Dr. J. Salta, and Dr. B. Barrera, all resident physicians of the hospital, gave us valuable coöperation. To all these we wish to express our sincerest thanks.

acts upon the malaria parasites in that phase of their life in which they are nourished and develop. When the nutritive activities cease by an arrest of the transformation of the hemoglobin into black pigment, and the reproductive phase begins, then quinine is ineffectual in its action.

With the development of organic chemistry new hope arose of synthetically building up specific remedies against malaria. All of these, however, that were claimed to be specifics, even if they had apparent antimalaric effect, proved to be far inferior to quinine and its derivatives. Only salvarsan, in certain cases of benign tertian infection and at the same time as a blood restituent, and methylene blue, in quartan fever, have been of value.

In 1907 Rabe(3) described the chemical constitution of the quinine molecule as consisting of one chinoline ring connected by a secondary alcoholic group with the so-called "loipon" portion; that is, the piperidine ring with two intermediate CH_2 radicals:



Giemsa(4) examined the therapeutic effects of many derivates. He found that only hydroquinin and quinethylin are superior to quinine and that any change in the bridge-carbon molecule necessarily lessens the antimalaric effect.

At the Tagung Deutscher Naturforscher und Aerzte, in Duesseldorf, September 22, 1926, the first announcement was made concerning "Plasmochin."

Schulemann, Schoenhoefer, Wingler, and Hoerlein(5) succeeded in preparing a chemical compound which they claim to be an

n-diethyl-amino-isopentyl-8-amino-6-methoxyquinolin, thus differing from quinine principally by lack of the "loipon" portion.

Some confusion has been created by calling this compound variously "beprochin," later on, "plasmochin," and now in English-speaking countries, "plasmoquine."

Roehl(5) found that this drug gave highly satisfactory results in canary birds infected with *Proteosoma praecox*. He administered 1 cubic centimeter of the solution for each 20 grams body weight and found the highest strength of quinine tolerated 1:200, the lowest effective 1:800; that is, the so-called chemotherapeutic index is 1 : 4. Roehl claimed to have found plasmoquine sixty times as effective as quinine with an index of about $\frac{1:1500}{1:50000}$ or 1 : 30.

Sioli(5, 6) experimented with the new antimalaric in forty cases of general paralysis therapeutically infected with tertian malaria. He showed that often with doses of 0.25 gram intoxications may occur; 0.15 gram daily was considered the upper limit. Sioli observed in one case after a total dosage of 0.6 gram in the course of eight days hepatic pain and cyanosis but without formation of methæmoglobin either in the blood or in the urine. Recovery was rapid, but the skin did not regain its natural color until three weeks later.

Muehlens(5, 7, 8, 9) treated one hundred seventy-two cases of naturally acquired human malaria with plasmoquine. These cases consisted not of first fevers but were all acute relapses or chronic cases. Muehlens notes that they had been treated under very favourable general conditions; that is, in a temperate climate (Hamburg), with sufficient food and rest in bed.

In benign tertian and quartan malaria this author found daily doses of from 0.05 to 0.1 gram, in a few cases even up to 0.15 gram, effective and stated that after the second or the third day of medication defervescence occurred and that parasites disappeared from the peripheral blood in five to seven days. He observed fewer relapses than after quinine treatment. Side reactions such as cyanosis of fingers, toes, lips, and face, and spasmodic gastralgia occurred now and then, the latter especially when plasmoquine was given on an empty stomach or in large individual doses of 0.05 gram. On the other hand none of the usual side effects after quinine medication such as bitter taste, deafness, tinnitus aureum, or dizziness was experienced.

In tertian and quartan infections plasmoquine is about as effective as quinine on both schizonts and gametocytes. However, Muehlens found in the treatment of æstivo-autumnal malaria that pure plasmoquine is not so efficient; he observed more relapses owing to its insufficient effect upon the subtertian schizonts. To prevent relapses quinine was added and the combination called "plasmoquine compound," which is now manufactured in tablets each containing 0.01 gram plasmoquine and 0.125 gram quinine sulphate. Formerly it had been manufactured in smaller tablets of 0.005 gram plasmoquine and 0.0625 gram quinine sulphate, which had been used for our experiment.

Muehlens states that—

> "For the first time we have found a medicament which causes the crescents to disappear within 4 to 7 days with the certainty of an experiment." He furthermore adds "that in acute infections of aestivo-autumnal malaria with many schizonts (rings ++++) and *without* gametes, plasmoquine treatment, immediately begun, nearly always prevented the formation of crescents."

The largest amount of plasmoquine he gave was 3.25 grams in sixty-eight days. He states that in none of his cases could gametocytes be found longer than seven days.

Muehlens's most interesting observation was the successful treatment of two cases of blackwater fever and of one case with petechiæ and ecchymosis in the skin and mucous membranes. The three cases were promptly cured by plasmoquine.

In a few cases he observed that crescents appeared, even after schizonts had disappeared, but these crescents disappeared very soon. In only one case the crescents, which appeared on the eighth day after the beginning of treatment and which had been discontinued just the day before, remained for a further seven days in the peripheral blood.

Muehlens reports that he observed no relapses among four cases of quartan infection, three relapses among forty benign tertian infections, and thirty-four relapses among forty-nine subtertian infections, after the administration of pure plasmoquine. He reports only four relapses in subtertian infection after plasmoquine-compound treatment and no failures in the tertian type. No severe symptoms of intoxication, even after daily dosage of 0.18 gram, were observed. Children and even babies tolerated the drug well.

Fischer(8) reports a prophylactic test with a ship's crew on the west coast of Africa. Thirty-nine members of the crew took, on three successive days of the week, 0.095 gram plasmo-

quine. He claims to have observed a morbidity of only 20 per cent for malaria compared with 25 to 30 per cent on other ships with quinine prophylaxis, 1 gram twice a week. Fischer means that the course of the disease was less severe, but he gave not only 0.055 gram plasmoquine and 0.5 gram quinine intramuscularly but later even quinine orally. For treatment Fischer thinks that plasmoquine was more willingly taken by the crew because it does not have the ill-effects of quinine.

In Talavera de la Reina, Spain, Roehl(8) treated successfully three tertian cases with pure plasmoquine, and three subtertian infections, but the latter remained all positive for parasites in the peripheral blood.

Schulemann and Memmi(8, 10, 11) treated over one hundred cases in Grosseto Hospital, Italy. Dosage: Three times 0.02 gram plasmoquine for seven days; four days interval; three times 0.02 gram plasmoquine, for three days; four days interval and so on for six weeks, if possible. Out of twenty-four tertian infections only one relapsed; four quartan infections, no relapse; insufficient effect on subtertian infections. With plasmoquine compound, three times 0.02 gram plasmoquine and 0.25 gram quinine daily, sixty-three cases of subtertian were treated. No parasites were found after the eighth day of medication. Thirteen cases relapsed during or after the intervals and between the medication days.

The authors mention the very interesting fact that changing from one medicament, be it plasmoquine or quinine, to the other, seems to act sometimes as a provocative, being followed by the appearance of parasites or fever. Two cases of blackwater fever were also cured with plasmoquine.

Side effects seldom occurred. Twice considerable cyanosis, once after three times 0.02 gram plasmoquine, the other after three times plasmoquine compound (0.02 plus 0.25), frequently slight livid bluish lips. Several times arrhythmia was observed. The authors mention especially having observed a marked lymphocytosis, in some cases up to 50 per cent. Gastralgia was rarely observed when plasmoquine was given on an empty stomach. Most of the complaints were psychotic, and "we frequently saw that this complaining of pains spread as an epidemic over one ward, while the other ward remained completely immune!"

Vomiting never occurred after plasmoquine and only twice after plasmoquine compound but stopped after continued medication of pure plasmoquine, therefore having been caused only

through quinine idiosyncrasy. The authors furthermore note and describe degeneration forms of adult parasites under plasmoquine treatment, as likewise occurs with quinine, but they observed such forms only in tertian infection. These forms show a complete, dark blue protoplasm with drop-shaped ramifications, partly cut off.

Mihajlo M. Radojicic(8) treated forty-nine cases of malaria in Skoplje, Jugoslavia, with pure plasmoquine. Nineteen cases were promptly cured after daily doses of 0.06 to 0.08 gram plasmoquine. "The parasites disappeared from the peripheral blood in 1 to 2 days and didn't reappear during further plasmoquine treatment." Seven cases of acute first subtertian fevers without crescents all remained free from gametocytes. Daily dose: Five times 0.02 gram plasmoquine. There were two relapses, one on the twentieth day after the beginning of treatment.

Ten cases had schizonts and crescents in the peripheral blood at the beginning of treatment. The author states that in these occurred "relapses much more frequently." Thirteen cases with only crescents gave the best results, the gametocytes all disappearing after five days. Gastralgia was never observed, cyanosis in only three cases.

A. Djokic and D. Stambuk(8) in Bitoly, Jugoslavia, treated one hundred two cases with plasmoquine. Generally 0.08 gram plasmoquine was given, the highest dose was 0.14 gram daily. In a very careful manner the authors divided the patients into several groups and gave them different combinations.

Gastralgia was seldom observed but cyanosis frequently. One case showed amaurosis, but this did not reappear when some days later plasmoquine again was given. Some statements might be quoted:

> Plasmoquine acted promptly upon tertian parasites (schizonts and gametocytes). Temperature dropped, splenomegaly was reduced, and the general condition improved rapidly. * * * We could not observe that in tertian infection plasmoquine reacts better upon new infections than upon relapses, nor is there any difference in its action on the sexual or asexual forms. Both forms are affected equally well and quickly.

In their cases the earliest time for the disappearance of parasites was one day and the longest five days. The authors conclude that in tertian infection pure plasmoquine may well replace quinine and is even superior to quinine in the quartan type. In subtertian infection the authors confirm Muehlens's observations of the insufficient effect of pure plasmoquine on

small rings, but the absolutely certain destruction of crescents, and the good effect of combined plasmoquine and quinine administration on both types. They also note that, especially on small rings, plasmoquine has somewhat of a provocative action, as already mentioned by Schulemann and Memmi.

Finally Djokic and Stambuk again direct attention to the outlook from an epidemiological standpoint in so far as "plasmoquinization" cuts the vicious circle of malarial transmission in crescent carriers.

G. Polychroniades(8) treated one hundred eighty-eight cases in Saloniki. Four tertian, two quartan, and thirty-eight subtertian cases were given plasmoquine, three times 0.02 gram daily. There were nineteen relapses in the subtertian form with nine cases showing persistently small rings. All tertian and quartan infections were cured. Eight cases showed cyanosis and eight gastralgia. Three quartan and one hundred thirty-nine subtertian cases were given plasmoquine compound (0.02 plasmoquine and 0.25 quinine) three times daily. In all cases the gametocytes disappeared rapidly between the second and the eighth day after treatment began. Small rings, however, disappeared between the second and the tenth day, but reappeared in fifteen cases, between the seventh and the twenty-third day. Twenty-two cases had abdominal pains, two showed cyanosis.

The author reports three blackwater cases cured by plasmoquine. The first, tertian infection, showed hæmoglobinuria with fever. After three days treatment (0.06 gram daily) parasites disappeared and the urine became normal without hæmoglobin (reaction of Rolland and Mayer). The temperature fell to normal on the sixth day. On the fourteenth, rings appeared again without either rise of temperature or hæmoglobinuria. Then plasmoquine compound was given. The parasites disappeared again but reappeared on the twenty-second day. Then 1 gram bichloride of quinine was given by mouth with the effect that the urine again became black for twenty-four hours. After one day interval plasmoquine compound was given for three days, this was repeated after five days interval. Parasites as well as hæmoglobinuria disappeared. Later quinine was again tried in increasing doses and tolerated up to 0.75 gram.

The second case had only fever which persisted for fifteen days. Hæmoglobinuria disappeared after twenty-four hours. On the twenty-first day tertian rings were found in the pe-

ripheral blood without fever. After administration of plasmoquine compound the parasites disappeared finally and no hæmoglobinuria occurred.

The third case (type not mentioned) had neither fever nor parasites in the peripheral blood. Only symptomatic treatment was given and hæmoglobinuria disappeared after twenty-four hours. On the eleventh day rings (type not mentioned) appeared, but without rise of temperature. After administration of plasmoquine compound the parasites disappeared rapidly and no hæmoglobinuria occurred. The author concludes:

> Notwithstanding minor side-effects, unimportant, like cyanosis of lips and nails, gastralgia, but not frequently (23 per cent), there is no contraindication to plasmoquine, and this includes even hæmoglobinuria and pregnancy. On the contrary according to our experiences, in certain of such cases it is quinine that would be contraindicated.

M. Sliwensky(8) treated in Burgas, Bulgaria, two hundred twenty-five cases of malaria in the hospital and fifty-nine ambulant. The author reports the usual good effect in the tertian and quartan types. Of eight quartan infections there was no relapse; among twenty-six tertian hospital cases one relapsed forty days after treatment with two times 0.04 gram plasmoquine for only five days; a second case relapsed after sixteen days, he had received the same dose (two times 0.04 gram plasmoquine) for seventeen days. This was obviously an inefficiently low dosage.

A third relapse occurred after twenty-one days in a patient who received plasmoquine compound (0.03 gram plasmoquine and 0.375 gram quinine sulphate) two times daily for eleven days. Among the eighteen ambulant tertian infections only one relapse was observed after eighty days; the dosage had been two times 0.02 gram plasmoquine for eight days.

Among one hundred twenty-five subtertian cases that were given plasmoquine compound (0.03 gram plasmoquine and 0.375 gram quinine sulphate) twice a day for five to twelve days, thirty-eight relapses occurred.

> In only a very few cases could crescents be found after eight days. In only one case after a sea-bath and during plasmoquine treatment could we observe a few crescents on the seventeenth day.

As a whole, plasmoquine compound was found by the author much superior to pure quinine medication on account of its certain effect on crescents.

Two cases of quinine idiosyncrasy with epistaxis and one case of blackwater fever tolerated plasmoquine well and were cured. The blackwater patient, female, 40 years old, with subtertian infection for about two months, had taken quinine. After 0.4 gram quinine a very severe attack of blackwater fever occurred with icterus, vomiting, coma, urine dark reddish brown. Under symptomatic treatment and plasmoquine, beginning with twice 0.01 to 0.05 gram, the patient improved quickly and tolerated quinine later on.

The author directs attention to two facts; namely, that babies, 3 to 14 months old, tolerate plasmoquine very well even in doses five times as large as adults, and, second, that even enormous enlargements of the spleen decrease very rapidly.

Cyanosis and gastralgia were only occasionally observed.

S. Manaloff-Sliven (12) reports ten cases from Bulgaria. One tertian case received six tablets of plasmoquine compound (six times 0.02 gram plasmoquine and 0.1 gram quinine sulphate) daily and became negative for parasites after four days.

Two patients with quartan infections had taken quinine for a longer period but still showed larger numbers of parasites. Both became negative for parasites on the fourth day; daily dosage 0.08 and 0.1 gram plasmoquine, respectively.

Each of seven patients with subtertian infections was given 0.06 gram plasmoquine. The author does not state why he treated tertian infections with plasmoquine compound and æstivo-autumnal infections with pure plasmoquine; it is no wonder that in these seven cases no sufficient action was observed and, besides, four relapses were noted. Cyanosis occurred only in one case.

M. Sliwensky, (13) in Sofia, Bulgaria, reports a very instructive observation which he calls: "Plasmoquine for controlling gametocytes from an epidemiological standpoint. (Der Gametenversuch mit Plasmochin in epidemiologischer Betrachtung.)"

In a distant village, Vajakeny, eighty-one carriers of gametocytes were treated and received 0.075 to 0.08 gram plasmoquine daily in one dose after dinner. He was able to treat sixty-four of the eighty-one for six days. Blood films were taken one day after treatment was finished, fifty days later and, for the third time, after four months.

All carriers who showed at the beginning only gametocytes (tertian 3, subtertian 18) remained free after four months.

Relapses after fifty days: Six of sixteen carriers with subtertian schizonts and gametocytes, two of twenty-two who had shown before only schizonts, one of two with tertian schizonts and gametocytes, and one relapse after four months in a patient with double infection (tertian and subtertian).

Cyanosis or gastralgia was never observed although the whole, comparatively high, dose of plasmoquine was administered at once.

The author concludes:

> 0.00125 gram plasmoquine per kilogram of body weight, in the form of plasmoquine compound for five to six days, is able to free the peripheral blood of crescent carriers of the three types for at least four months. Especially in countries with marked so-called "seasonal-malaria," this fact should be made use of as a most efficient and economic measure. It is possible to give at once the whole daily dose of 0.06–0.08 gram plasmoquine without any ill effect.

Baermann and Smits(14) stated that in their experiments with eleven tertian and one quartan case there were the usual good effects of plasmoquine (four times 0.02 gram); no relapses in eighty days. With plasmoquine compound, however, one of three tertian cases relapsed in fifty days.

The authors even gave pure plasmoquine to nine subtertian infections, and it is no wonder they had five relapses. It is notable in this experiment that among seven cases without crescents even under plasmoquine treatment crescents appeared in four cases. Furthermore, eight relapses were treated with plasmoquine compound (0.01 gram plasmoquine and 0.125 gram quinine sulphate four times a day). Six remained free, while in the blood of one case after fourteen days treatment schizonts as well as crescents remained demonstrable. The other case died.

> Weight 48.4 kilograms, hæmoglobin 70, pulse 68. Spleen one finger breadth, no albumin, one subtertian ring in four fields. Treatment, plasmochin 0.02 gram, four times daily. On the third day he had some cyanosis, became unconscious, temperature 39.2° C. (102.55° F.), leucocytes 16,000, albumin without casts. He was given quinine intravenously and intramuscularly with disappearance of parasites from the circulation, but he died next day with a rapid fall of temperature and with a crescent in the blood. No malaria parasites were found except some crescents in the spleen. The liver showed patchy, fresh, and very silght necrosis.

Plehn(15) reports a quinine-resistant strain of æstivo-autumnal type in the case of a sailor who was infected in Karachi. This man received large doses of different medicaments, including "beprochin," and still developed schizonts as well as gametocytes but finally was cured.

In various hospitals of the United Fruit Company(16) in Central America one hundred ninety-four cases of malaria were likewise treated with plasmoquine and plasmoquine compound. Cortes from Preston, Cuba, Brosius from Almirante, Panama, Macphail from Quirigua, Guatemala, and Nutter from Tela, Honduras, agree with Muehlens in their favorable reports; but Whitaker, who had only pure plasmoquine without quinine, reports from the same hospital in Tela that, besides the well-known insufficient effect of pure plasmoquine in æstivo-autumnal infection, even three cases of tertian and one of quartan infection after 0.08 to 0.1 gram for four to six days remained positive for parasites, although the fever was controlled just as well as with quinine. One death occurred in Preston, and the report is quoted in full on account of its importance.

The patient was a male negro, 35 years of age. He was admitted suffering from a severe attack of aestivo-autumnal malaria and was treated with the new drug, plasmochin compound. On the 4th day of his treatment, after the fever had disappeared and the blood film was negative for malarial parasites, he developed a profound anaemia, leucocytosis, jaundice, nausea (vomiting), and somnolence. The urine was negative for haemoglobinuria. He died within 48 hours after the onset of this sudden attack. The toxic influence of plasmochin compound was suspected to have played an important rôle in the cause of death.

Microscopic Examinations by Dr. F. B. Mallory (U. F. A. 75)

Heart.—Negative.

Spleen.—Numerous lymphocytes and plasma cells in the pulp; many endothelial leucocytes in the blood sinuses containing red blood corpuscles, often in great numbers (10 to 20 and more). Malarial pigment occurred occasionally in the red blood corpuscles both free and in phagocytes.

Liver.—Endothelial cells lining sinusoids were prominent, occasionally phagocytic, and some contained pigment. Some of the liver cells in the centers of the lobules contained vacuoles in which were dots and occasionally threads of fibrin (hydropic degeneration). Rarely a liver cell was necrotic and was being invaded by endothelial leucocytes. There was slight lymphatic infiltration of periportal connective tissue.

Kidney.—Moderate oedema of the tubules.

Cerebrum.—Negative.

MICROSCOPIC DIAGNOSES

Malarial infection of the spleen.
Marked phagocytosis of red blood corpuscles in the spleen.
Early stage of central necrosis of the liver.

REMARKS

It is unfortunate that no bone marrow was included with the other tissues. The anaemia may have been due to destruction of red blood corpuscles by the malarial infection. The phagocytosis in the spleen would seem to indicate this. The beginning necrosis of the liver cells is probably due to the toxic action of the plasmochin, but it is not nearly so active as chloroform or carbon tetrachloride. Possibly plasmochin has a destructive effect on the red blood corpuscles.

The other patient in Preston hospital developed mild symptoms of jaundice and decrease of hæmoglobin under a daily dose of 1 gram quinine and 0.08 gram plasmoquine (that is, 16 tablets) but recovered.

Observation of side effects, such as cyanosis, nausea, and abdominal pains, differs widely in the different hospitals and might partly depend on the individuality of the observers. In this respect we refer to Memmi and Schulemann's description of the epidemic spreading of complaints over a ward. Whereas in Tela Hospital eleven of fifty-four patients under pure plasmoquine treatment showed cyanosis or epigastric pains and two of twenty-eight under plasmoquine compound treatment felt "slight nausea," only four of one hundred eleven patients from the three other hospitals had any complaint at all. Besides, Whitaker from Tela Railroad Hospital observed these ill effects only after administration of 0.1 gram and adds that after reduction to 0.08 gram plasmoquine "these results were infrequent."

One case with malarial infection and insufficient quinine treatment may be quoted. This, under 0.06 gram plasmoquine and 0.75 gram quinine daily, develop icterus and slight hæmoglobinuria on the fifth day, but they disappeared after twenty-four hours without interruption of the medication. In general the experience in the four hospitals of the United Fruit Company confirms to a large degree the statements of Muehlens concerning clinical symptoms and parasiticidal action. The reports note especially rapid reduction in size of the spleen after administration of either plasmoquine or plasmoquine compound and indicate a very important field of usefulness in pregnancy, even in its late stage where no such

uterine contractions occurred after plasmoquine compound as are observed frequently under pure quinine medication.[2]

Philip Manson-Bahr(17, 18) reports twenty-eight cases. He confirms the good effect of plasmoquine in ten tertian cases and the well-known insufficient effect in the subtertian type. His results with plasmoquine compound were satisfactory in five cases of æstivo-autumnal type and even in five cases of benign tertian. He observed several toxic side effects, three cases showed methemoglobinuria (in two of them the chocolate-brown blood contained methemoglobin) within twenty-four hours of the "cyanosis" after 0.4 gram plasmoquine. The daily dosage was 0.12 gram. These two patients had a typical hæmolitic icterus. Manson-Bahr says: "The attack resembled a mild blackwater-fever which ran a favorable course."

Cherefeddin(19) reports from Gureba-Institute, Constantinople, three cases of subtertian infection which were cured by pure plasmoquine. He is the only author who claims pure plasmoquine superior to quinine against subtertian schizonts. He says: "The action of plasmoquine upon the rings of æstivo-autumnal type is stronger than that of quinine; it acts certain and well on subtertian gametocytes."

Eiselsberg(20) reports a poisoning on the fifth day of plasmoquine medication. The daily dose was far under the permitted dose of 0.15 gram, the total dosage was 0.2 gram. The patient had no malaria but a very chronic pempigus conjunctivæ. He became—

> By that time (2nd December) yellow, weak with much epigastric pain and, after the last pill, vomited and lost consciousness. His tempera-

[2] After this paper had been finished (January, 1928), the 16th Annual Report of the United Fruit Company (1927) had been published, which confirms as a whole the very satisfying experience with plasmoquine as published in the 15th Annual Report. It seems, however, that the physicians of the company observed occasionally some toxic side effects, which made them decrease the amount of plasmoquine to 0.04 gram in combination with from 1 to 3 grams quinine daily. We consider this amount of plasmoquine too small, and we think that such heroic doses of quinine are in excess and that they give no better results than smaller doses, which in acute cases with alarming symptoms may be given intramuscularly.

An outstanding observation was made by Barber and Komp. They found that small doses of plasmoquine may so cripple gametocytes that they are rendered incapable of forming healthy oöcysts. By this toxic action upon the crescents, mosquitoes feeding on these inviduals do not become infected. Deeks says: "This observation is exceedingly important, and if it is confirmed, plasmoquine must be considered of paramount importance in malaria control."

ture was 39.6 (103.3) and the urine deep brown. He came under the care of Eiselsberg next day. He was still vomiting but not bringing up blood. Urine dark brown with brown sediment and giving guaïacum test, even when diluted 500 times; much albumin; red corpuscles; an occasional leucocyte; no casts: Liver very tender; spleen two fingers. Red corpuscles 2,400,000 with poikilocytosis and anisocytosis. By 6 p. m. the red corpuscles numbered 1,550,000; the serum was brownish red with a strong direct bilirubin reaction and with urobilin strongly positive. Blood transfusion and dextrose improved matters. On the fourth of December the red blood corpuscles numbered 1,300,000, the whites 15,700; on the fifth methemoglobin was spectroscopically established in the urine, apparently the first spectroscopic examination made. Rapid improvement followed.

G. Carmichael Low(21) in a short note writes against plasmoquine and without mentioning his results reports four cases. In three of them he observed "cyanosis" and of the fourth reports "sickness after the use of plasmoquine," but he does not give any further details.

W. Fletcher and K. Kanagarayer(22) report ninety-seven cases of malaria treated with plasmoquine. The authors state that the effect in tertian and quartan type "upon the parasites was equally striking," and that "plasmoquine proved at least equal to quinine." In subtertian fever they observed, as is sufficiently known, not a satisfactory action with the pure plasmoquine, but had to employ plasmoquine compound. Concerning side effects the authors mention only two cases with cyanosis, one with gastralgia, and two with fever and collapse while undergoing treatment but without any abnormal findings in the urine, so that the authors do not consider this illness due to plasmoquine.

Recently, P. Ignacio(23) published a very interesting paper on the plasmoquine treatment of twenty-nine cases of malaria, most of them in the Philippine General Hospital, Manila. This work was done long after we had started our studies and was under the direction of the Research Committee of the College of Medicine, Manila. Briefly it may be noted that the author saw the well-known effects reported by Muehlens, when the drug was administered properly. Unfortunately, the author had not a sufficient supply of plasmoquine compound, so that "we have used a combination of plasmoquine tablets and quinine bisulphate capsules." For blood examinations, no thick films were made, but "thin smears obtained one half to one hour after the injection (adrenalin or strychnine) were always used in the blood examination using the Wright's stain."

Side effects were observed as usual, but "the untoward effects are, therefore, few and mild and that they disappeared promptly when the drug is withheld." The author, following Muehlens, says of plasmoquine compound: "It appears that plasmoquine compound is more powerful than quinine."

Pharmacological tests were made by Eichholtz(8) and Le Haix and De Lind van Wyngaarden.(24) Eichholtz found that in cats 2.5 to 5 milligrams plasmoquine per kilogram weight, given hypodermically, produces methaemoglobin formation. Then he states:

1. Intravenous injection of plasmoquine affects in cats, dogs and rabbits the coördinate action of the heart by suppressing systoles or duplicating them, producing arrhythmia perpetua in higher doses.

2. Adrenalin, in small amount, prevents this interruption. The amount of adrenalin which is formed and flows into the blood after psychic emotion or muscular activity acts in like degree.

3. Quinine, given in sufficient dose (i. e. 2 to 4 milligrams intravenously), also counteracts.

Le Haix and De Lind van Wyngaarden showed that considerable differences prevail in the different animals. Whereas per kilogram weight the fatal dosage for cats is 5 milligrams, given either hypodermically or intravenously, and 7.5 milligrams if given orally, rabbits may die after the administration of only 3.5 milligrams, but tolerate up to 20 milligrams given hypodermically, and even 225 milligrams if given by oral application. Cats seemed to recover more quickly than rabbits after poisoning. Death occurs with symptoms of dyspnœa, asphyxia, bradycardia, and arrhythmia. The authors note specially the formation of methæmoglobin.

Plasmoquine can be identified(25) after medication in the urine by extracting the urine (200 to 300 cubic centimeters) after alkalization with ether. After adding 2 per cent acetic acid the ether is evaporated. The residue is taken up with glacial acetic acid and tetra-chlor-benzoquinone, so-called chloranil:

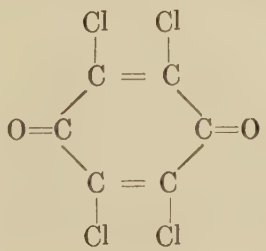


TABLE 7.—*Records of additional cases.*

No.	Name.	Type of parasite.	Medication.	Days after treatment.												
				1	2	3	4	5	6	7	8	9	10	11	12	13
1	Mr. A.	○ E	5×2	○○												
2	Mrs. A.	○ E	5×2	○			○									
3	Baby A. 9 months old.	○ E	3×1	○			○									
4	Bi	○○ I E	6×2	○○		○	—				— ‖		‖			
5	H. Ch.	T○⊕ ⁂	6×0.02	○⊕ ⁂		D D I		D						—		‖
	BLOOD-PICTURES OF CASE 5.															
	Number of leucocytes		7,200				7,900	6,000								
	Promyelocytes		—	2	—	—	—	—								
	Myelocytes		—	1	—	2	1	—								
	Youthly nonlobulated		2	2	—	—	—	½								
	Nonlobulated polymorphonuclears		12	7	—	5	3	2½								
	Lobulated polymorphonuclears		48	37	—	43	441	42								
	Eosinophiles		2	1	—	2	5	7								
	Lymphocytes		25	35	—	43	43	44								
	Monocytes		11	15	—	5	4	4								
	Basophiles		—	—	—	—	—	—								

A bluish-green or bluish color appears, according to the concentration.

Plasmoquine containing urine gives a precipitate with mercury iodide-potassium iodide, as does quinine, but which persists in heating.

Plasmoquine, on the other hand, does not give the thalleioquin reaction, which remains characteristic for quinine.

The diazo reaction is positive for plasmoquine in dilutions of 1 : 100000.

Our own experience with plasmoquine includes ninety cases of authochton-acquired malaria.[3] Some were private patients, but the majority were cases in San Lazaro Hospital, Manila. Most of the latter patients came from Novaliches district, Rizal Province, about 25 kilometers north of Manila, Luzon, where a new water-supply system for Manila is under construction. The blood films of the private cases were all stained with Giemsa's stain, examined and checked by the two authors separately. From the hospital cases, however, the blood films were taken by one of the resident physicians (Dr. J. Salta or Dr. B. Barrera), stained in the beginning with Wright's stain and latter with Giemsa's stain also, the latter being by far the better method. Another thick blood film and, if necessary, a thin smear too, was stained and examined by the authors themselves. Both findings were checked and usually agreed. In the very rare cases of nonagreement they were considered as positive.

Thirty-nine pure tertian infections were treated with plasmoquine as a shown in Table 1 and 4. The daily dosage was 0.02 gram plasmoquine three times, which was given without interval

[3] After this paper had been already finished (January, 1928), we had the opportunity to treat five more cases of malaria with plasmoquine. As Table 7 shows, the same good effects of plasmoquine medication were obtained in one pure tertian and four subtertian infections. Of the latter one was a baby, 9 months old, which got three times one tablet plasmoquine compound (0.005 gram plasmoquine and 0.0625 gram quinine sulphate) a day and tolerated it well. The blood picture of the tertian case was followed up and is also shown in Table 7. In this case the lymphocytosis after plasmoquine medication is pronounced as well as the appearance of a few very young forms of leucocytes; namely, myelocytes and even promylocytes. We do not decide if this answering on behalf of the bone marrow and the spleen is to be considered as a precipitated regeneration caused by the malarial infection or by the toxic effect of the drug.

TABLE 1.—*Tertian type of malaria treated with plasmoquine.*

[○, schizonts; ⁘, merozoits; ⊕, gametocytes; !, abundant; ⌊, change in the medication; ‖, end of treatment.]

No.	Name.	Type of parasite.	Daily dose.	Days after treatment.							
				1	2	3	4	5	6	7	8
			g.								
1	M. M.	○	0.12	○			—		—		—
2	R. G.	○	0.12	○			—		—		—
3	S. M.	○	0.12	○		—			—		—
4	P. C.	○	0.12		○ ⁘ !			○		—	
5	C. V.	⁘ !	0.12		⊕ ⁘ !		⊕ ○			—	
6	M. C.	○	0.12			○		—		—	
7	A. C.	○	0.12		—			—		—	
8	M. L.	○	0.12			○ ⊕		—		—	
9	A. N.	○	0.12		○		—			—	
10	B. G.	○	0.12		—		—			—	
11	M. S.	○	0.12		—		—			—	= =
12	C. Ve.	○	0.12		—			—	‖		
13	J. L.	○	0.12		—		—		—	—	= =
14	F. H.	○	0.24				○	—		—	
15	M. B.	○	0.24		—		—		—	‖	
16	M. N.	○	0.24		○		—		—		—
17	A. A.	○	0.24		○ ⊕		—		—		—
18	A. Ri.	○ ⁘ ⊕ !	0.24			○	—	—	—	—	—
19	M. Lu.	○ ⊕	0.24		○ ⊕ ⁘ !	⌊ 0.24	—		—		—
20	F. R.	○	0.12		○ ⊕ ⁘ !	⌊ 0.24	—		—		—
21	A. M.	○	0.12		○ ⊕		—		—		—
22	A. P.	○ ⊕	0.24		○		—		—	⌊ 0.12	—
23	J. D.	○ ⊕ ⁘ !	0.24		○		—		—	⌊ 0.12	— ‖
24	P. V.	○	0.24								

25	J. Ca.	○⊕	0.32			○⊕	0.12		—		—
26	J. Ma.	○⊕	0.12		○⊕		—		—		—
27	d. l. R.	○	0.12		—		—		—	‖	
28	S. J.	○	0.12		○⊕		⊕		—		—
29	F. Di.	○⊕⊙!	0.12		○		—		—		—
30	F. Sa.	○⊕⊙!	0.12			—		—		—	
31	N. Du.	○⊕	0.12			—		—		— ‖	
32	F. Po.	○⊕	0.12		○⊕		—		— ‖		
33	J. Me.	○⊕	0.12		—		—				
34	Ag.	⊕⊙!	0.12		○⊕				—		—

No.	Name.	Days after treatment.												
		9	10	11	12	13	14	15	16	17	18	19	20	21
1	M. M.			— ‖										
2	R. G.	‖												
3	S. M.		— ‖											
4	P. C.	—	‖											
5	C. V.	—			—		— ‖							
6	M. C.	— ‖												
7	A. C.	— ‖												
8	M. L.	—	‖											
9	A. N.	—	‖											
10	B. G.													
11	M. S.													
12	C. Ve.													
13	J. L.													
14	F. H.													
15	M. B.	—	‖											
16	M. N.													
17	A. A.	‖												

TABLE 1.—*Tertian type of malaria treated with plasmoquine*—Continued.

No.	Name.	Days after treatment.												
		9	10	11	12	13	14	15	16	17	18	19	20	21
18	A. Ri	‖												
19	M. Lu		—	‖										
20	F. R.	‖												
21	A. M.	‖												
22	A. P.	‖												
23	J. D.													
24	P. V.							⊕0.12		○⊕		—		—
25	J. Ca.		—	‖										
26	J. Ma.		— ‖											
27	d. l. R.													
28	S. J.		—											
29	F. Di.	‖			—		—							
30	F. Sa.													
31	N. Du.													
32	F. Po.													
33	J. Me.													
34	Ag.		—	(a)	(a)	(a)	(a)	—						

[a] Without medication.

TABLE 2.—*Aestivo-autumnal type of malaria treated with plasmoquine.*

[○, schizonts; ⁘, merozoits; ☽, crescents; !, abundant; ⌊, change in the medication; ‖, end of treatment.]

No.	Name.	Type of parasite.	Daily dose.	Days after treatment.																	
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	F. A.	○	3×2	○	○☽			○		○		—		—		— ‖							
2	T. C.	☽	3×2			○		○		○		○		—		—		—		—	‖		
3	G. P.	○☽	3×2			—		—		—			—	‖									
4	K. M.	○	3×2				○		—		—		—		— ‖								
5	A. R.	○	3×2			○		○			—	—		— ‖									
6	M. d. G.	○☽	3×2			○☽		○		—		—		— ‖									
7	J. T.	○	3×2		○			○		○		○			—		—		—			— ‖	
8	V. R.	☽!	3×2			☽		○		—		—		—	‖								
9	V. G.	○	3×2			○		—		—		—			—		— ‖						
10	E. V.	○	3×2			○☽		○		—		—		—	—	‖							
11	A. Ro.	○!	3×2		○!			—		—		—		‖									
12	R. P.	○	3×2			○		—		—		—	‖										
13	G. P.	○	3×2	○		☽	○☽		—		○		○		—			—	‖				
14	M. F.	○!	3×4		○			—		—			— ‖										
15	V. Z.	○	3×4	○		○		—		—		—		—	‖								
16	M. J.	○	3×4		○		—		—		—		—	‖									
17	G. G.	○	3×4			—			—			—	‖										
18	A. P.	○☽	4×4		—		—		—		—												
19	B. A.	○	4×3		—		—		—		—		—		— ‖								
20	T. M.	○	4×4		○		—		—		—	‖											
21	E. M.	○!	4×5		○!		○		—	⌊3×2	—		—	‖									
22	E. Ta.	○☽⁘	3×2		○		—		—		— ‖												
23	A. Ra.	○	3×2		○		—		—														
24	J. K.	○	3×2		—		—																
25	B. B.	○☽	3×2		—		—		—	⌊[a]	—		—			‖							
26	F. Schn.	○!		○!	○!	○!	○	○	—	—	—	→	[b]										

[a] Without medication.

[b] For daily dosage, see Table 7.

up to the day of discharge from the hospital, the longest period being fourteen days. Whereas in most patients the tertian parasites can no longer be found on the fourth day after the beginning of treatment, and have already disappeared even on the second day in some cases, in a few cases the peripheral blood is not found free before the sixth or seventh day. With the exception of these rare cases we can confirm Muehlens's first report. But, on the other hand, and as will be explained later, we do not consider pure plasmoquine as a convenient antimalaric for tertian infections unless one is working in one of the rare districts of the world where only tertian fever prevails and neither æstivo-autumnal nor double infections occur.

Defervescence occurs early.

We have had no opportunity to treat quartan infections, and this type is extremely rare in the Philippines.

We treated twenty-seven cases of simple subtertian infection with plasmoquine compound as is shown in Table 2. The daily dosage was two tablets three times in the beginning; that is, 0.03 gram plasmoquine and 0.375 gram quinine sulphate. Later, for case 14, we increased the amount to four tablets three times a day; that is, 0.06 gram plasmoquine and 0.75 gram quinine sulphate. The quantity was doubled because in a few cases of double infection (tertian and æstivo-autumnal type) the parasites persisted in the peripheral blood to the twenty-second and even to the twenty-fifth day after plasmoquine medication was begun and continued daily *without interruption* (see case 14, Table 3).

Special interest attaches to case 26, for this was the most carefully observed patient in the group (one of the private patients of Dr. H.). Daily blood examinations were made. Later, after discharge from the hospital, the patient carelessly took too small an amount of plasmoquine compound and came back after four weeks not only with fever, loss of fifteen pounds, and headache, but also with a few crescents in the thick blood film. Crescents had never been found before.

As Table 2 shows, subtertian parasites were found in our cases longer than Muehlens states in his experiences. With a dosage of two tablets three times, whereas crescents disappeared very soon and could not be found after the fourth day of administration, schizonts persisted until the ninth and even the tenth day (case 13. G. P.). It might be stated that crescents appeared in three cases on the second and the third day after treatment began, where they had not been observed before.

This somewhat "provocative" effect of the drug will be discussed later.

Interesting observations were made in our eighteen cases with double infection as shown in Table 3.

Whereas these cases revealed all the difficulties in making an exact differential diagnosis between tertian and subtertian young schizonts (small rings) in the thick blood film, in all these cases examinations of thin smears were necessary for the existence of Schueffner dots, and enlargement or reduction in size and darker coloration, respectively, of erythrocytes, and for finer structure of the parasite's protoplasm.

Cases 1, 4, 5, and 13 showed only tertian schizonts in the first blood film examined. Cases 1 and 4 received two tablets of pure plasmoquine three times a day (0.12 gram daily). Case 1 showed on the second day small subtertian rings. On the fourth day crescents appeared, but disappeared three days later after plasmoquine compound (two tablets three times a day) was administered. In case 4 crescents appeared on the sixth day after treatment with pure plasmoquine had begun and two previous blood examinations were found negative for any parasites. The day after administration of plasmoquine compound the crescents were found no more.

Case 5 received four tablets of pure plasmoquine three times a day (10.24 grams) and showed small subtertian rings in abundance two days later. After daily administration of four tablets three times a day of plasmoquine compound these subtertian rings remained for five days more.

Case 13 with tertian rings received 0.12 gram pure plasmoquine daily. On the eleventh and the twelfth day after the beginning of treatment the blood examination was negative. On the fifteenth small subtertian rings appeared and were abundant on the seventeenth day. Plasmoquine compound, two tablets three times a day, was given, and seven days later the peripheral blood was free.

Cases 3, 6, and 15 showed subtertian rings. After administration of plasmoquine compound, two tablets three times a day, case 3 revealed on the third day tertian schizonts, which were found together with subtertian rings. He left the hospital one day later.

Case 6 showed tertian schizonts together with subtertian two days after treatment with plasmoquine compound was begun. Two days later the peripheral blood was found negative for both types of parasites and remained so.

TABLE 3.—*Double malarial infections treated with plasmoquine.*

[○, schizonts; ⁘, merozoits; ⊕, gametocytes; ☽, crescents; !, abundant; ⌊, change in the medication; ‖, end of treatment; E, æstivo-autumnal; T, tertian.]

No.	Name.	Type of parasite.	Daily dose.	Days after treatment.						
				1	2	3	4	5	6	7
1	de V.	○T	0.12		○E		○E ☽	⌊3×2		—
2	A. L.	○T	3×2		○E			—		
		○E								
3	J. R.	○E	3×2			○T	‖			
						○E				
4	F. P.	○T	0.12		—		—		☽	
5	E. P.	○T!	0.24		○E!		⌊3×4	○E!		
6	D. D.	○E	3×2		○T		—		—	
					○E					
7	D. J.	○T	3×4			—		—		
		○E								
8	A. F.	○T⊕	4×4		—		—		— ‖	
		○E								
9	D. M.	○T	4×4		— ‖					
		○E								
10	J. O.	○T	4×4		○T⊕		—		—	
		○E			○E					
11	de J.	○T	4×4		○E	⌊3×3	—		—	
		○E								
12	L. d. C.	○E ⁘ ☽!	3×4		○E		—		—	
		○T⊕!			⊕○T					

No.	Name.	Type of parasite.	Daily dose.	3	7	9	11	12	15	17
13	J. D.	○ T	0.12	○ T	○ T	○ T	—	—	○ E?	!○ E

No.	Name.	Type of parasite.	Daily dose.	3	5	7	9	12	14	16
14	M. R.	○ T ○ E	3×2	○ T ○ E	○ T ○ E	○ T ○ E	○ E	○ E!	○ E!	○ E

No.	Name.	Type of parasite.	Daily dose.	2	3	4	6	8	10	13
15	M. D.	○ E	3×2	○ T	⌊0.12	—	—	—	○ E	⌊3×2 ⌊○ E

TABLE 3.—*Double malarial infections treated with plasmoquine*—Continued.

No.	Name.	Days after treatment.									
		8	9	10	11	12	13	14	15	16	17
1	de V.		—		—			—		‖	
2	A. L.	—	‖								
3	J. R.										
4	F. P.	D	⌊3×2	—		—		—		—	=
5	E. P.	○		—		—			— ‖		
6	D. D.		— ‖								
7	D. J.	— ‖									
8	A. F.										
9	D. M.										
10	J. O.	—									
11	de J.	—		—	‖						
12	L. d. C.	—		— ‖							

No.	Name.	18	20	22	24	27	29	31			
13	J. D	⌊3×2	○E	○E	—	—	—	— ‖			

No.	Name.	18	20	22	25	27	29	31	33	35	
14	M. R.	○E	○E	○E	○E	—	⌊3×4	—	—	— ‖	----

No.	Name.	15	17	20	22	25	28	30	32		
15	M. D.	○E	○E	○E	○E	⌊3×4 —	—	—	— ‖	----	----

In case 15 only tertian schizonts were observed on the second day. The following day 0.12 gram pure plasmoquine was given and continued daily. The blood examination was negative until the tenth day after treatment was originally begun, when subtertian rings reappeared. Three days later plasmoquine compound, two tablets three times a day, was given. The parasites were still present on the twenty-second day. Though the blood examination was negative on the twenty-fifth day, the dosage of plasmoquine compound was doubled (four tablets three times a day), and the peripheral blood remained free.

Cases 2, 7, 9, 10, and 11 showed both young schizonts of tertian as well as of the subtertian type. The parasites had already disappeared in case 7 by the third day.

In case 2 only subtertian rings were found on the second day and had disappeared by the time of the next examination, the fifth day.

In case 11 there were present, besides the tertian and the subtertian schizonts on the second examination, also tertian gametocytes; these had already disappeared by the third examination two days afterwards.

Case 8 showed tertian and gametocytes and schizonts besides æstivo-autumnal schizonts in the first-examined blood film; they disappeared very quickly and could not be found two days afterwards or subsequently.

Case 12 was an exceptionally heavy infection with abundant tertian and subtertian parasites of each stage, gametocytes as well as crescents included. On the second day crescents had disappeared, and there remained only a few tertian gametocytes besides both types of rings. The thick film on the fourth day was negative and further blood pictures remained the same.

Case 14 showed small rings of both types. He received two tablets three times a day. On the ninth day the tertian parasites had disappeared, but increased numbers of subtertian rings were observed during the two following examinations. These young subtertian schizonts were, however, found in decreasing numbers until the twenty-fifth day. Though two days later the blood examination was for the first time negative, the medication was doubled and the peripheral blood remained free.

In two of the three cases in this table where the peripheral blood remained positive for parasites over a longer period it is remarkable that previous medication of pure plasmoquine for some days had been given. Discussion might be raised as to

how far a certain "accustoming" of the parasites may be responsible for this fact.

Table 4 shows six cases which erroneously received quinine after originally plasmoquine treatment was begun.

Cases 2, 3, 4, and 5 with simple tertian infections received 0.12 gram pure plasmoquine daily. The peripheral blood was found free of parasites in two cases on the third day, in one on the fourth, and in one on the seventh day after treatment began.

In case 1 only tertian schizonts, merozoites, and gametocytes were found. On the ninth day small subtertian rings were observed in the absence of tertian forms.

Case 6 showed tertian rings. The second day after the beginning of treatment only small subtertian rings were found. The fifth day not only these small rings remained but crescents also appeared under pure plasmoquine administration. The following day plasmoquine compound was given. Though crescents were no longer found, the small rings persisted until the tenth day. This observation reminds us of cases 13 and 15, of Table 3, where likewise *pure plasmoquine treatment was*

TABLE 4.—*Tertian type of malaria and double infection in which treatment with plasmoquine was interrupted; further treatment with quinine.*

[○, schizonts; ⁘, merozoits; ⊕, gametocytes; ☽, crescents; T, tertian; E, æstivo-autumnal; ⌊, change in the medication; Q, quinine given.]

No.	Name.	Type of parasite.	Daily dose.	Days after treatment.						
				1	2	3	4	5	6	7
			g.							
1	L. F.	○ T ⁘ ⊕	0.12	○			○			
2	T. R.	○ T	0.12	○				○		—
3	P. Qu.	○ T	0.12	○			—	Q		
4	M. D.	○ T	0.12	○		—	Q			
5	V. Z.	○ T	0.12			—	Q			
6	F. C.	○ T	0.12		○ E			E ○ ☽	⌊3×2	○ E

No.	Name	Days after treatment.									
		8	9	10	11	12	13	14	15	16	17
1	L. F.		○ E				Q				
2	T. R.		—			—	Q				
3	P. Qu.										
4	M. D.										
5	V. Z.										
6	F. C.			○ E	Q						

TABLE 5.—*Three special cases of malaria.*

[○, schizonts; T, tertian; E, æstivo-autumnal; ⊕, gametocytes; !, abundant; ⌊, change in the medication; ‖, end of treatment.]

No.	Name.	Type.	Daily dose.	Days after treatment.												
				1	2	3	4	5	6	7	8	9	10	11	12	13
1	A. E.	○ T	*g.* 0.12				—		—	[a]	○			○ ‖		

No.	Name.	Type.	Daily dose.	3	7	10	13	15	17	20	22	25	28	30	32	35	37
2	T. A.	○ E	[b]	○			○				○	○ ⌊3×2					‖

No.	Name.	Type.	Daily dose.	3	6	8	10	13	14–38	39	41	43
3	L. de C.	○ T	*g.* 0.12	○ T	○ T⊕	○ T	○ T	○ E	[c]	○E ⌊3×2	○ E ! !	○ E !

[a] Without further medication. [b] Three times 1 tablet. [c] Under quinine treatment; æstivo-autumnal schizonts always present.

antecedent and the question of "accustoming" had been already raised.

Some cases merit special attention and are shown in Table 5.

Case 1 with simple tertian infection received 0.12 gram pure plasmoquine daily, over a period of six days. On the fourth day after treatment began the parasites had already disappeared from the peripheral blood. On the seventh day the patient refused to take any more medicine, either plasmoquine or quinine. Two days later tertian rings appeared again in the peripheral blood and remained there until the patient was discharged some days later.

Case 2 was a 12-year-old boy, with small æstivo-autumnal schizonts in the peripheral blood. One tablet three times a day only was given. Several times (see table) parasites were found up to the twenty-fifth day, when the medication was doubled. Three days later the parasites had disappeared and remained so until the thirty-seventh day, when the patient left the hospital. This evidently proves that even in children plasmoquine compound in half dose is in no way sufficient and the normal dose is well tolerated by them. This was also observed in case 4, Table 1, a girl of 7 years with simple benign tertian infection. The child received from the very beginning of treatment the full amount of 0.12 gram pure plasmoquine and tolerated it well, except for slight cyanosis of the finger tips.

Case, 3, a man of 24 years, showed in the beginning tertian schizonts in the peripheral blood. Under administration of pure plasmoquine, 0.12 gram daily, a few tertian gametocytes were found on the sixth day. On the thirteenth day small æstivo-autumnal rings were observed. From the following day to the thirtieth day (that is, over a period of twenty-four days) quinine sulphate, 1.8 grams daily, was given, but subtertian schizonts still persisted. Then plasmoquine compound, two tablets three times a day, was administered. After two days the subtertian schizonts were abundant in the peripheral blood. When the patient left the hospital two days later (that is, the forty-third day after treatment originally began), the parasites were found in decreased but still considerable numbers.

CONCLUSIONS

Concerning the action of pure plasmoquine in benign tertian infections we are able to confirm the good effect on all forms of the parasite as first reported by Muehlens. However, we

TABLE 6.—*Blood pictures in malaria.*

Specimen No.	Patient.	So-called youthly non-lobulated polymorphonuclears.	Nonlobulated polymorphonuclear forms.	Lobulated forms.	Lobulated "ring" forms.	Nonlobulated eosinophiles.	Lobulated eosinophiles.	Basophiles.	Monocytes.	Lymphocytes.
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
1	A., after 0.12 gram plasmoquine + quinine.	------	3	60	------	------	3.5	------	4	29.5
2	L. Cr., after 1.29 grams plasmoquine + 44.3 grams quinine.	------	2	49	------	8	--------	------	6	35
3	F. Schn.	------	1	73	------	------	0.5	------	9.5	16
4	-----do.	2	2	60	------	------	3.5	------	8	24.5
5	-----do.	2	1.5	54.5	2	------	2.5	------	8.5	29
6	-----do.	------	2	58.5	0.5	------	3	------	5	31
7	-----do.	------	1.5	64.5	------	------	1.5	------	4.5	28
8	-----do.	------	1	62.5	------	------	2	------	4.5	30
9	-----do.	1	3	65.5	------	------	3	------	4.5	23
10	-----do.	0.5	1.5	61	1	------	2.5	------	4	29.5
11	F. Schn., relapse.	0.5	4	68.5	------	------	—!	------	5	22
12	F. Schn.	0.5	2.5	59	------	------	2.5	------	8	27.5
13	-----do.	------	1.5	60.5	------	------	6	------	5	27
14	-----do.	0.5	2	59.5	------	------	3	------	5	30
15	-----do.	------	1	62.5	------	0.5	3.5	------	6	26.5
16	-----do.	------	2	53.5	------	1	6	------	6.5	31

gave slightly larger doses (namely, 0.12 gram daily) in the beginning and found it valuable sometimes to increase the dose to 0.24 gram daily. Under such medication defervescence occurs early and, whereas in many cases parasites had disappeared on the second day after the beginning of treatment, in none of our cases could we find parasites for more than six days.

Splenic enlargement rapidly decreases under plasmoquine medication. Case 85, a private patient of Doctor Moreta whom he courteously sent us, previously had malaria. He had received quinine and showed no more parasites in the peripheral blood but had still a very large spleen. After plasmoquine the spleen rapidly decreased in size.

In a few cases tertian gametocytes, which could not be found in the beginning, appeared under plasmoquine medication, but disappeared again very soon.

In æstivo-autumnal infections it seems to us that with six tablets of plasmoquine compound daily (that is, 0.03 gram plas-

moquine and 0.375 gram quinine sulphate) the parasiticidal effect, though much superior to quinine, is yet not so striking as claimed by authors in Europe. However, it should be kept in mind that the general conditions in the Tropics, poorer food, and, doubtless, lower resistance of the poorer class are less favorable than conditions in European or American hospitals.

In a few of our cases the parasites persisted to the eleventh day, although we gave larger doses than originally suggested by Muehlens. However, this author has more recently recommended from 0.06 gram plasmoquine and 0.75 gram quinine to 0.08 gram plasmoquine and 1.0 gram quinine daily.

The effect of plasmoquine compound upon crescents is strongly pronounced, as Muehlens stated. However, as this author has already reported, we have observed likewise some cases in which crescents appeared for the first time under plasmoquine administration but soon disappeared with continued treatment.

In double infections we noticed frequently somewhat of a *provocative effect of plasmoquine.* This means in cases where primarily only tertian parasites were found, after administration of pure plasmoquine subtertian schizonts and even crescents appeared. In these cases treatment was continued with plasmoquine compound. On the other hand, under plasmoquine-compound administration the tertian parasites appeared in the peripheral blood, where only subtertian forms had been previously present. *But in these cases, only tertian schizonts appeared and never the sexual forms contradictory to the above-mentioned appearence of crescents in the suspected simple tertian infection.*

A few "plasmoquine-resistant" cases were observed by us, as shown in Tables 3 and 5.

Concerning the side effects we observed frequently more or less pronounced cyanosis which, however, was in none of the cases so alarming as to require the withholding of further plasmoquine medication. This cyanosis is often first observed on the nails and the finger tips, on the mucous membrane of the lips, and in the mouth. The face shows a very typical, pale, livid gray. The droplet of blood obtained by pricking the finger pad has a characteristic dark bluish-red color.

One of our cases even received up to 0.15 gram plasmoquine with 0.875 gram quinine daily, and showed no alarming side effects.

Though this cyanosis occurs more frequently and generally is more pronounced after medication with pure plasmoquine, we

have also noticed the same after administration of plasmoquine compound. We have not observed any relationship between this cyanosis and the severity of the malarial infection.

Muehlens, in his first publication,(5) considered circulatory disturbances responsible for the cyanosis. More recently, however, he has accepted the general consensus of opinion(9) that formation of methæmoglobin is the real cause. Not only methæmoglobin could be found after plasmoquine medication by Eichholtz(8) in man and by Le Haix and De Lind van Wyngaarden(24) in cats and rabbits, but the latter authors also showed that in vitro it may be formed by plasmoquine from the blood of men, cats, rabbits dogs, horses, cattle, sheep, and pigs.

Gastralgia was observed frequently in ward patients and especially if one patient had started to complain, the others followed. In none of our private cases did we hear any severe complaints. We therefore agree perfectly with Memmi and Schulemann,(8, 10, 11) Whitaker,(16) and others, that the degree of these abdominal pains is widely dependent on psychological factors, both of the patient and the observer. Though generally abdominal pains seem to occur more frequently after pure plasmoquine, they are also noted after plasmoquine compound medication.

The differential leucocyte count was made from a Giemsa-stained thin smear. This specimen was not made on a slide but on a cover glass after the procedure of Naegeli and as recently described by Hasselmann.(26) We have observed no remarkable effect of plasmoquine administration, except lymphocytosis as described by Memmi and Schulemann.(8) Table 6 shows sixteen examples of the leucocyte pictures. Concerning any direct visible action of plasmoquine upon the form or shape of the plasmodium, we have seen these curious parasites only upon or even just outside the border line of the erythrocyte, where the plasmodium itself seemed to be dying and stained very palely. We did not observe the so-called "Zerreissungsformen" as first described by Schaudinn(27) after quinine, nor could we feel thoroughly convinced of the "Degenerationsformen" as described after plasmoquine treatment by Memmi and Schulemann(10) and by Manson-Bahr.(18)

OUTLOOK

As already stated quinine is far from being the *therapia magna sterilisans* for malaria eradication. With the exception

of Billet(28) most authors, including Barber,(29) Bass,(30) Bignami,(2) Darling,(31) Gualdi,(32) James,(33, 34) Jancsó,(35) Macfie,(36, 37) Martirano,(32) Polettini,(38) Purjesz,(39) Rieux,(40) Schaudin,(41) Loewenstein,(42) Thomson,(43) Wenyon,(44) Werner,(45) and Yorke,(36, 37) consider that quinine does not affect the gametocytes and that patients receiving even 2 grams of quinine daily are infective for the biting mosquito. Furthermore, Yorke and Macfie(36, 37) showed that under experimental conditions only daily quinine treatment for ten days after the infectious bites could prevent the infection. Similar observations were made by Kirschbaum(46) in paralytics after injections of malarial blood.

As shown by James and Shute(47, 48) in their notable investigation with experimental infection of 2,630 female *Anopheles maculipennis,* it is most striking that a relatively small proportion of malarial-infected persons are infective to mosquitoes. They say:

> During this work it has been our experience that some patients with induced malaria are not at all infective to anopheles at any period of their malarial course, that others are only moderately so, and that rarely one comes across a patient who is strikingly infective.

The authors conclude that those patients are "good infectors" who carry a large number of gametocytes as found on blood examination, but in contrast to the opinion of Darling(31) and others who claim that one gametocyte to five hundred leucocytes (that is, twelve per cubic millimeter of blood) should be sufficient for infecting the mosquito, they had many failures even if the number of gametocytes was considerably in excess of this. The authors, therefore, have the impression that the quality of the sexual form, perhaps, the character of "ripeness," plays a more important rôle.

It is evident that apart from the mosquito conditions the incidence of gametocytes in man is the most important factor in the spread of malaria. From the epidemiologic standpoint cases of subtertian malaria treated with quinine may be for weeks a greater danger in labor camps than even the recently infected cases one finds in field surveys. Wenyon(44) and Clark(49) have shown that even after hospital treatment with up to 4 grams of quinine daily and without fever and symptoms, a large percentage of such cases remain gametocyte carriers. In view of this we may direct more attention to the fact that malaria is a "household disease" and as such might often

be dealt with in the houses rather than with antilarval methods. It should be remembered that Le Prince and Proctor(50) proved the efficiency in Panama of systematic mosquito catching in dwellings, as lately again recommended by James. However, conditions in the Philippines are somewhat different, since *Anopheles minimus*, the chief vector, has never been found resting in houses.

With this in mind the demonstrated gametocidal activity of plasmoquine permits us to return to Robert Koch's(51, 52) postulate that it is relatively more important to extirpate the malaria infection in the infected human carrier than to eradicate the mosquito as suggested by Ronald Ross.(53, 54) In order to avoid any misinterpretation we want to state positively that under favourable conditions in comparatively small areas mosquito-control work may remain the standard method. Examples such as Ismaïlia, the Panama Canal Zone, the Federated Malay States, some places in Dutch East India, the "bonifications" in Italy (incidentally, though not directly, antilarval), and lastly the very effective work in Jugoslavia as reported by Hasselmann (55, 56, 57) are widely enough known. The cost of this mosquito-control work justifies itself and can be maintained only in large commercial and industrial centers or populous residential districts. In rural districts and especially in large plantations we still consider the sufficient treatment of the diseased men as the most effective procedure. One of the world's most extensive plantation undertakings, the United Fruit Company, in its last annual report,(16) suggests the same view. (Also compare the Proceeding of the Seventh Congress of the Far Eastern Association of Tropical Medicine, Calcutta, the different views of Colonel James and Sir Malcolm Watson.)

In this respect we have in the new plasmoquine a remedy to cut the vicious circle of malarial infection in the human carrier by destroying the gametocytes, which are alone the infective source for the biting mosquito.

A few words may be said about the special conditions in the Philippines. Our patients came mostly, as already mentioned, from the Novaliches district, Rizal Province, about 25 kilometers north of Manila. This has been long known as a heavily infected malarial district. Judging from morbid incidence *Anopheles minimus* is supposed to be chiefly responsible for transmission, though *Anopheles barbirostris, philippinensis, hycranus, fuliginosus,* and *rossi* are found there too. Whereas *A. fuligi-*

nosus, hycranus, and *philippinensis* breed mostly in still water only, *A. barbirostris* and *rossi* are encountered in both still and running water. *Anopheles minimus,* the vector, is here found only in clear running water under shade. *Anopheles barbirostris* is usually found associated with *A. minimus,* but in more slowly moving rivers.

The Rockefeller Foundation and the Philippine Health Service have done some good work in San José, Mindoro; on the Calamba sugar estate, Laguna; and in the districts of Novaliches and Angat, where the new water supply for Manila is under construction. Quininization and mosquito-control work (the later mostly by the use of Paris-green powder) against *Anopheles minimus,* the chief vector, gave results which cannot be separated from each other. A prolonged and sufficient treatment of the patient, with the goal of freeing him from malaria gametocytes and especially from crescents, will no doubt prove still more effective than prophylatic medication with plasmoquine. We perfectly agree with the United Fruit Company, which urges *that no malaria patient should be discharged from the hospital who still has gametocytes in the peripheral blood* and that the discharged patients should remain under observation for a certain time. These means of freeing carriers from gametocytes are much more effective and economic. Such a desideratum, practically impossible with quinine, is now brought within practical lines through the addition of plasmoquine to our antimalarial armamentarium.

It may be stated that we consider 0.12 gram pure plasmoquine a day, given in dosis refracta, as a sufficient quantity for benign tertian infections. We have never seen any alarming side effect with this dosage that would have required the discontinuance of plasmoquine medication.

It is, however, more convenient to administer plasmoquine compound at once in cases where the least suspicion of a possible subtertian infection or a double infection exists. We refer to Muehlens,(9) who says:

> In all tropical countries where double infections with subtertian fever occur, plasmoquine compound should be given to avoid relapses of subtertian fever after tertian or quartan, respectively, have stopped.

Whereas this author thought temporarily to recommend smaller doses, he has increased them more recently(9) to 0.06 gram plasmoquine togather with 0.75 gram quinine a day; that is, six of the larger or twelve of the smaller tablets of plasmo-

quine compound. In our cases and in consideration of the small size of the average Filipino we found daily doses of 0.03 gram plasmoquine and 0.375 gram quinine sulphate sufficient in most of the cases, though much larger doses were well tolerated, as the tables show. In this respect special attention may be directed to case 25, Table 1, with tertian infection, who was given daily 0.32 gram plasmoquine for three days and 0.12 gram plasmoquine for eight days, altogether 1.92 grams plasmoquine without interruption in the course of eleven days without any considerable side effect. Case 26, Table 2, with æstivo-autumnal fever received up to 0.15 gram plasmoquine together with 1.875 gram quinine sulphate a day and tolerated it well. Even in this case, with the comparatively heroic dosage, two more rises of temperature occurred as shown in the text figure.

This fever curve, besides, is typical and might be given as an example. Furthermore, in this case, which was a European of 19 years and became infected on a kapok plantation in Novaliches district, it is noteworthy that crescents appeared on the thirty-eighth day after plasmoquine-compound treatment began, though the patient took the drug for four weeks but only very irregularly and in too small doses; namely, two small tablets a day for after treatment. *We cannot speak of a certain plasmoquine-fast strain of the parasite, because under continued and proper medication of the same drug, the parasites disappeared and did not reappear.*

Our observations are not sufficient to formulate proper conclusions concerning relapses, for most of the ward patients had to be discharged from further hospital observation to their respective camps. It may, however, be stated, that even of these laborers only one (case 23, Table 1) came back within five months with malaria, whereas laborers from the same camps, who had been treated with pure quinine, frequently came back for hospital treatment. Very often the latter then obtained plasmoquine treatment and were finally cured.

Case 26, Table 2, as already mentioned, had a relapse and even developed crescents. Muehlens(9) and Memmi and Schulemann(10) admit that this may happen but very seldom.

We did not observe, as reported by Vad and Mohile(58)[4] and by Baerman and Smits,(14) that the natives tolerate plasmoquine better than white people.

[4] These authors recently reported very satisfying results of plasmoquine treatment in sixteen cases of malaria.

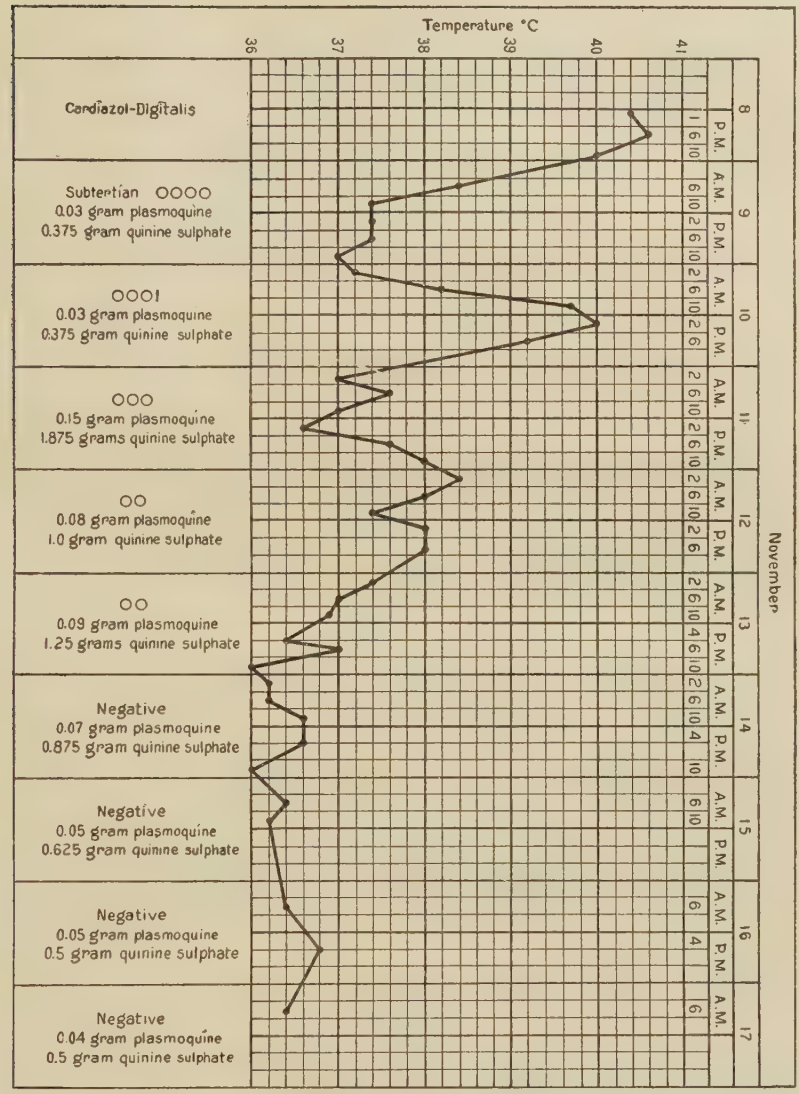


FIG. 1. Temperature chart of a malarial patient treated with plasmoquine and quinine.

Concerning the differential leucocyte count Memmi and Schulemann(8) report a lymphocytosis up to 50 per cent after plasmoquine treatment. In some of our cases we could verify this. Table 6 shows sixteen blood pictures.

Finally, the question arises as to the value of plasmoquine in the Philippines. There are about 25,000 deaths reported each year due to malaria. Good work has been done since 1922 under the direction of the International Health Board, the Philippine Health Service, and the United States Army and Navy authorities. Field work, started in Olongapo, Zambales; Del Carmen, Pampanga; and various districts in Laguna Province and carried over certain parts of the country proved successful. Even in San José, Mindoro, once known as the "white man's grave," quinine prophylaxis together with spraying of Paris-green powder have done much to better conditions, but we must not expect too much of these measures. For instance, during the second week of February, 1926, in one of the Novaliches camps there was a morbidity of more than 20 per cent of all laborers who had to be transferred for hospital treatment, and this was in the very neighborhood of Manila! Conditions, however, have improved; the vector in the Novaliches district is apparently *Anopheles minimus* alone, and all streams and running waters are now continuously sprayed. In December, 1927, an epidemic outbreak of malaria among the Igorots near Ibulao River, Mountain Province, Luzon, was reported,(59) not to speak of the vast areas in Mindanao where only malaria prevents exploitation of one of the gobe's most fertile soils.

We wish to direct attention to the more economical possibility of breaking the vicious circle of malaria in man by administering plasmoquine, not prophylactically, but as sufficient treatment of the infected, thus freeing him from gametocytes and making him sterile for the biting mosquito, the ineradicable animal of tropical countries.

SUMMARY

1. Ninety cases of naturally acquired malarial infection were treated with plasmoquine.[5]

[5] We had no opportunity to treat cases of pneumonia with plasmoquine as did H. Schlesinger, who reports early defervescence after its administration. Muench. med. Wo. No. 11 (1927) 479.

2. Forty of these cases were tertian infections and received from 0.12 to 0.32 gram of pure plasmoquine daily in dosis refracta. They were freed from parasites in from two to six days after treatment began.

3. Thirty-one of the cases were simple æstivo-autumnal infections and received "plasmoquine compound" on an average from one tablet three times (child) to five tablets four times a day. Each tablet contained 0.005 gram plasmoquine and 0.0625 gram quinine sulphate. They were freed from parasites in from two to ten days after treatment began.

4. Eighteen cases were double infections. Those that showed in the first blood examinations only tertian parasites were given pure plasmoquine, which was changed to plasmoquine compound as soon as the double nature of the infection was revealed. The other cases, with both types of parasites or with only subtertian forms in the beginning, were given plasmoquine compound at once.

5. In all cases—most pronounced in case 85—splenic enlargement rapidly decreased.

6. It seems that in double infections plasmoquine has somewhat of *a provocative effect;* that is, where only one type of parasite is found in the peripheral blood, after administration of pure plasmoquine the subtertian forms appear in the peripheral blood; and after administration of plasmoquine compound, on the other hand, the tertian forms often appear; but in these cases only tertian schizonts appeared and never the sexual forms contradictory to the above-mentioned appearance of crescents in the suspected simple, benign, tertian infection.

7. It is remarkable that small æstivo-autumnal rings persisted for a longer time in the peripheral blood if previous medication of pure plasmoquine had been given. Therefore the question of a certain "accustoming" arises.

8. Whereas our observations do not warrant final judgment concerning relapses, these were exceptionally few as compared with relapses after quinine medication.

9. Side effects, such as gastralgia and abdominal pains, cyanosis of the lips and the finger tips, and paleness of the skin, may occur, especially after pure plasmoquine, but never required the discontinuance of the medication. On the other hand these possible *side effects make medical supervision absolutely indispen-*

sable [6] and plasmoquine unfit for self treatment, after treatment, or prophylaxis without this medical care. Likewise, we do not consider plasmoquine suitable for prophylaxis, on a large scale, except under strict daily medical supervision for a possible sterilization of a certain population, say for about ten days, with the goal of freeing all possible carriers from gametocytes.

10. We recommend the following doses:

A. In tertian infections—

0.10 gram plasmoquine daily, best given as one tablet of 0.02 gram, five times a day. This dose may be eventually doubled.

B. In æstivo-autumnal or in double infections—

Five times a day one tablet plasmoquine compound, each of 0.01 gram plasmomoquine and 0.125 gram quinine sulphate; that is, 0.05 gram plasmoquine and 0.625 gram quinine sulphate a day; that is, at least 0.001 gram plasmoquine per kilogram weight.

Although we consider these doses sufficient in most cases, in one case with tertian infection we gave up to 0.32 gram plasmoquine daily and in the course of eleven days altogether 1.92 grams plasmoquine without interruption and without any considerable side effects. Another case (26, Table II), with subtertian fever, received up to 0.15 gram plasmoquine together with 1.875 grams quinine sulphate a day and in the course of seventy-six days a total of 1.62 grams plasmoquine and 22.25 grams quinine sulphate, also without any alarming side-effects.

11. Our experience confirms to a large extent, Muehlens's first report that this new antimalaric is superior to quinine in tertian infection and its action as specifically "gametocidal" in subtertian fever.

12. We may compare plasmoquine with the "Altsalvarsan," which was very soon improved after its discovery by Ehrlich himself. Therefore, we agree with the following statement of Manson-Bahr: (17)

Plasmoquine has to be regarded as the first of a new series of antimalarial synthetic drugs, and not as the climax of what has already been accomplished. The future is distinctly hopeful as regards the synthesis of a still more efficient antimalaric compound.

[6] We, therefore, cannot follow the views of Benecke, but are in line with the oficials of the United Fruit Company (Sixteenth Annual Report).

The administration of plasmoquine [7] in combination with quinine as plasmoquine compound has been demonstrated to be markedly successful in freeing the victim of malaria from gametocytes. This brings nearer accomplishment *the original suggestion of Robert Koch to break the vicious circle of malaria by destroying the sexual forms of the malarial parasite in the human carrier.*

REFERENCES

1. The Lancet (August 19, 1916).
2. Marchiafava, E., and A. Bignami. 20th Century Practice of Medicine. Wm. Wood & Co., New York 19 (1900).
3. Rabe. Bericht d. Deutsch. chem. Gesellsch. 40 (1907) 2013.

[7] Plasmoquine is manufactured and sold in tablets, each containing 0.02 gram. Plasmoquine compound is manufactured and sold in tablets. The dragées and the larger tablets contain 0.01 gram plasmoquine and 0.125 gram quinine sulphate, the smaller tablets one-half these amounts; namely, 0.005 gram plasmoquine and 0.0625 gram quinine sulphate. However, they are no longer manufactured. More recently ampoules for hypodermic and intravenous use have been put on the market.

The question is frequently asked, at the current prices of the two drugs which is more expensive, treatment with quinine or with plasmoquine compound and pure plasmoquine.

The base treatment of 30 grains of quinine sulphate per day, say for five days and then 10 grains per day for eight weeks would require one hundred forty-two 5-grain tablets; the schema of Nocht, Manson-Bahr, Ziemann, and others, would demand somewhat less, about ninety-five 5-grain tablets; that is, about 31 grams. At current prices 5-grain tablets cost 1.4 centavos each. Therefore, the base treatment would cost about 2 pesos (equivalent to 1 dollar in United States money); that of Nocht, and others, would cost about 1.30 pesos.

On the other hand treatment and after-treatment with plasmoquine compound would require according to Muehlens—and this is rather the upper limit in our experience—132 of the larger tablets. The local price for this amount would be a little over 5 pesos, if based on the price of 1,000 pesos for 25,000 of the larger tablets as the cheapest sold unit.

The administration of quinine and plasmoquine in separate tablets would be somewhat more complicated, but at the same time considerably cheaper—about 2.98 pesos, if based on the price of 1,650 pesos for fifty thousand 0.02-gram tablets of pure plasmoquine. It would be necessary to give only three of these tablets daily, which would be equal to the amount of plasmoquine in six tablets of "plasmoquine compound" and 0.75 gram of quinine in the form of two and one-half 5-grain quinine sulphate tablets.

Therefore, the cost of plasmoquine compound treatment is about as 5 to 2 or 1.3 as compared with quinine treatment. However, the difference in efficiency; that is, difference between probably not destroying the gametocytes on the one hand and of almost certainly destroying them on the other, cannot be estimated in money.

4. GIEMSA, G. Arch. f. Schiffs-Trop. Hyg. No. 8 (1926) 342.
5. HOERLEIN, ROEHL, SIOLI, and MUEHLENS. Beihefte z. Arch. f. Schiffs-Trop. Hyg. etc. 30 No. 3 (1926).
6. SIOLI, F. Die Naturwissenschaften 14. Jhrg. (1926) 1160.
7. MUEHLENS, P. Die Naturwissenschaften 14 Jhrg. (1926) 1162.
8. MEMMI, G., and W. SCHULEMANN. Ueber Plasmochinbehandlung der natuerlichen Malaria. Beiheft z. Arch. f. Schiffs-Trop. Hyg. 31 (1927).
9. MUEHLENS, P. Deutsche med. Wchnsch. (1927) 46–46.
10. MEMMI, G., and W. SCHULEMANN. Riv. di Malariologia 6 No. 1 (1927) 40; Policlinico Sez. Prat. 34 No. 25 (1927) 883; and Klin. Wchnsch. 6 No. 23 (1927) 1093.
11. SCHULEMANN, W. Vorter, med. naturw. Ges. in Muenster. M. m. W. 32 (1927) 1394.
12. MANALOFF-SLIVEN, S. Arch. f. Schiffs-Trop. Hyg. 31 No. 11 (1927).
13. SLIVENSKY, M. Arch. f. Schiffs-Trop. Hyg. 31 No. 11 (1927).
14. BAERMANN, G. and E. SMITS. Geneesk. Tijdschr. v. Nederl. Indie 67 (1927) 151.
15. PLEHN, A. Arch. f. Schiffs-Trop. Hyg. No. 5 (1927) 202.
16. United Fruit Company. Medical Department. Fifteenth and Sixteenth Annual Reports: Experience with Plasmochin (1926 and 1927).
17. MANSON-BAHR. P. Proc. Roy. Soc. Med. 20 No. 6 (1927) 919.
18. MANSON-BAHR, P. The Lancet (Jan. 7, 1928).
19. CHEREFEDDIN, O. Arch. f. Schiffs-Trop. Hyg. 8 (1927) 375.
20. EISELSBERG, K. P. Wiener klin. Wo. 40 No. 16 (1927) 525.
21. CARMICHAEL, Low G. The Lancet (Feb. 4, 1928) 359.
22. FLETCHER, W., and K. KANAGARAYER. Ind. Med. Gaz. 62 No. 9 (1927).
23. IGNACIO, PATRICIO. Bull. San Juan de Dios Hosp. 2 No. 1 (1928) 21.
24. LE HAIX and DE LIND VAN WYNGAARDEN. Klin. Wo. 19 (1927) 857.
25. SCHULEMANN, SCHOENHOEFER, and WINGLER. Arb. ueber Tropenkrankheiten. Festschr. f. Prof. Nocht. Hamburg, L. Friedrichsen (1927) 507.
26. HASSELMANN, C. M. Arch. f. exp. Path. u. Pharm. 108 No. 1–2 (1925).
27. SCHAUDINN, F. Arb. a. d. Kaiserl. Gesundheitsamt. 19 (1903) 224.
28. BILLET, A. Bull. soc. Path. Exot. 6 No. 5 (1913).
29. BARBER, M. A. Philip. Journ. Sci. § B. 13 (1918) 1–47.
30. BASS, C. C. South. Med. Journ. 14 No. 4 (1921) and Am. Journ. Trop. Med. 2 No. 4 (1922).
31. DARLING, S. T. Proc. Canal Zone Med. Assoc. (1909).
32. GUALDI and MARTIRANO. Annali d'igiene sperimentale (1901).
33. JAMES, W. M. South. Med. Journ. 6 No. 5 (1913).
34. JAMES, W. M. New York Med. Journ. 98 No. 2.
35. JANCSÓ, N. L' état du paludisme en Hongrie pendant les derniéres années. Att. d. soc. stud. d. malaria 9 (1908).
36. YORKES and MACFIE. Trans. Roy. Soc. Trop. Med. & Hyg. 18 No. 1–2 (1924).
37. YORKES and MACFIE. Trans. Roy. Soc. Trop. Med. & Hyg. 19 No. 3 (1925).
38. POLETTINI, U. I gameti del sangue circolante secondo il trattamento chininico curativo del'infezione malarica. Malaria 1 No. 3.

39. Purjesc. Cit. after A. Celli, La Malaria in Italia durante al 1912. Ann d'igiene sperimentale 24 No. 2 (1914).
40. Rieux, J. Bull. de la Soc. de Pathol. Exot. (1913) No. 3.
41. Schaudinn, F. Cit. H. Ziemann. Menses Handb. d. Tropenkrankh. 3 (1924).
42. Loewenstein, E. Zentralbl. f. Bakteriologie 83 (1919).
43. Thomson, D. Ann. trop. med. a. Paras (1911) No. 1, 6 No. 2 (1912).
44. Wenyon, C. M. Journ. Roy. Army Med. C. 37 (1921) 354.
45. Werner, H. Arch. f. Schiffs-Trop. Hyg. 18 No. 20 (1914).
46. Kirschbaum, W. Arch. f. Schiffs-Trop. Hyg. 31 No. 8 (1927).
47. James, S. P., and P. G. Shute. Report on the first Results of Laboratory Work on Malaria in England. Publ. by Malaria Commission, Health Organ. League of Nations. Geneva (1926).
48. James, S. P. Arb. ueber Tropenkrankh. Festschr. f. Prof. Nocht. Hamburg. Verl. L. Friedrichsen (1927) 220.
49. Clark, H. C. Am. Journ. Trop. Med. 7 No. 1 (1927).
50. Le Prince, J. A. U. S. Publ. Health Report 61 No. 25 (1926) 1220.
51. Koch, Robert. Deutsche med. Wchnsch. 5 (1899).
52. Koch, Robert. Deutsche med. Wchnsch. No. 37 (1899); (1900) Nos. 5, 17, 25, 34, 46, and 49.
53. Ross, Ronald. The Prevention of Malaria. London, J. Murray (1911).
54. Ross, Ronald. Memoirs; with a full account of the great malaria problem and its solution. London, J. Murray (1923).
55. Hasselmann, C. M. Deutsche Med. Wchnsch. (1926) No. 17–19.
56. Hasselmann, C. M. Arch. f. Schiffs-Trop. Hyg. (1926) 205–207.
57. Hasselmann, C. M. Med. biol. Abend. d. Univ. Frankfurt a. M. (Feb. 8, 1926).
58. Vad and Mohile. Ind. Med. Gaz. 62 No. 8 (1927).
59. Manila Daily Bulletin (Dec. 16, 1927).
60. Benecke. Arb. ueber Tropenkrankh. Festschr. f. Prof. Nocht. Hamburg. Verlag. L. Friedrichsen (1927) 23.

ILLUSTRATION

TEXT FIGURE

FIG. 1. Temperature chart of a malarial patient treated with plasmoquine and quinine. 121

NOTES ON MALARIA TRANSMISSION

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FOUR PLATES

Banks,[1] in 1907, claimed to have produced artificial malarial infection in *Anopheles ludlowii* (salt-water type) and reproduced the disease in a volunteer. His evidence, however, is inconclusive. He showed microphotographs of sections of supposedly infected salivary glands, the only microphotographic illustrations of sporozoites I know of in available Philippine literature on malaria.

Walker and Barber,[2] in 1914, experimented with *Anopheles minimus* Theobald (*A. febrifer* Banks), *A. rossii* Giles, *A. barbirostris* van de Wulp, *A. hyrcanus* Pallas, and *A. maculatus* Theobald, and succeeded in producing the highest infection rates in the stomachs and the salivary glands of *A. minimus*. They concluded that *A. minimus* is probably the most important transmitter of malaria in the Philippines.

In a subsequent paper Barber [3] included *A. maculatus* with *A. minimus* as one of the chief transmitters of malaria although to a lesser extent.

By circumstantial evidence the Rockefeller investigators [4] incriminated *A. minimus* and *A. ludlowii* (fresh-water type), stream and river breeders, respectively, as the main vectors.

The present notes are preliminary in nature and give briefly the recent findings of the malaria section of the Philippine Health Service on malaria transmission during its first year of existence.

Little material will be presented, as the major part of the year was spent in routine surveys, organization, and establishment of control areas.

[1] Philip. Journ. Sci. § B 2 (1907) 513.
[2] Philip. Journ. Sci. § B 9 (1914) 381.
[3] Philip. Journ. Sci. § B 10 (1915) 177.
[4] Tiedeman, Journ. Prev. Med. No. 3 1 (1927). Mieldazis, Ann. Rep. Philip. Health Service (1925) 196.

The merits of the study of malaria transmission by experimental or by natural infection will not be gone into for the present, nor will the question of why one species may be a very important vector in one country and not in another be touched.

The method followed in the dissection of wild-caught mosquitoes and the result so far attained will be given. Microphotographs are presented, particularly those of the sporozoites, to compare with those of Banks in *Anopheles ludlowii.* Different stages of the oöcyst in the stomach are also illustrated. A section of the thoracic ganglion of *Culex* (Plate 5, fig. 2) is also given for comparison with Bank's microphotographs of sporozoites. Comparison of this figure with Banks's Plate 9, fig. 4, would seem to show that Banks mistook the nuclei of the neurones for sporozoites.

ANOPHELES SURVEYS

In a survey of sixty-nine malarious places in Luzon and Mindoro, *Anopheles minimus,* a stream breeder, was found in sixty-four (93 per cent) of the places, and the predominant species in fifty-three (77 per cent). It is believed that if larval collections were made during the malaria seasons in all these places, *A. minimus* would probably be found in almost all and the predominant species. There may be a few localities where *A. minimus* is not the natural vector, but this remains to be shown by further observations. In a survey of twenty-five places in Mindanao and Sulu, of which eleven were malarious, where malaria was present *A. minimus* was always found, alone or with the other species; while when *A. minimus* or its potential breeding place was absent, the other species present or abundant, there was invariably no malaria. Of course, the presence of *A. minimus* does not necessarily imply the presence of malaria. It was on the basis of the Mindanao findings that "species control" against *A. minimus* was recommended by the writer and approved by the Advisory Committee on Malaria Control in April, 1927. This limits Paris-green control to streams and irrigation ditches found to be *A. minimus* breeders.

In localities with permanent streams it has often been said and also observed that the peak of the malaria season coincides with the dry season (rice harvesting) and with the abundance of *A. minimus* breeding when the water is clear and at a constant level. During the rainy season the flooding carries the larvæ away, hence lower malaria incidence. There are places, however, where the malaria season starts after the rain and

decreases during the dry season. This condition has been found to be due to the formation of rain or temporary streams, the *A. minimus* breeding places, which as a rule dry out during the dry season. Both of the above conditions apparently exist in the Novaliches water project, in Rizal Province, Luzon, with more cases during both the dry and the rainy season. Of course, the nature of the work (excavation and filling) and consequent lowered resistance and exposure during rains, might have caused more cases and relapses.

HABITS OF ADULT ANOPHELES MINIMUS

No systematic study has been made of the habits of *Anopheles minimus*. What will be given here are only incidental observations from September to December, 1927, inclusive, in La Mesa (Novaliches water project), while looking for the insects for dissection purposes. La Mesa is the second worst malaria district encountered in about two hundred surveys, with 84 per cent splenomegaly and 53 per cent positive blood in children and at least 46 per cent blood positive among active laborers who receive 10 grains of quinine daily.

The adult mosquito is typically "wild" in that it is very seldom found in the ordinary nipa house at night, much less in the day time. The only occasions on which they have been caught during the day time were when they were imprisoned inside wire screens. During the period of heavy catches they have shown preferential harborage in two houses out of about seventy-five, and incidentally where most of the new malaria cases were registered. Why this is so has not been studied, but it may be that these houses are suitably located in the mosquitoes' line of flight; due to favorable winds; near the nearest breeding places beyond the control areas; or, that the houses are firmly built and not subject to much vibration.

Most of the catches were made outside the houses and by exposure of the body and the limbs of the catchers. Flashlight is indispensable to spot them. The best time to see them in Novaliches is in the latter part of the evening. Mosquito traps have not yet been studied.

Of over twenty-seven hundred adult *Anopheles* caught, only two were males. This may be due to the fact that as most of the catches were by exposure the nonbiting males were not attracted; or, the area being under control, the breeding place from which the females come is beyond the 1.5-kilometer limit; or for some unknown reason.

DISSECTION

The basis for identification of species will not be gone into, suffice it to say that Strickland's Manual was used and found to be a very simple guide.

Method.—For a successful dissection the primary requisite is a mosquito freshly killed with a drop of chloroform or tobacco smoke applied to the mouth of the test tube containing the insect. Insects long dead are unsatisfactory, as they are hard and brittle. After the species has been determined, a fine sewing needle in a handle (needle 1) is thrust into the thorax, either dorsal, lateral, or ventral side, preferably toward the caudal half in order to avoid the salivary glands. The legs and the wings are removed with a pair of entomological forceps or the fingers. Place a drop of normal salt solution on the middle of a slide, and with the aid of another dissecting needle (needle 2) carefully detach the mosquito from needle 1 and lay it on its side on the slide, the head on the edge of the salt drop. Place needle 1, held with one hand, on the thorax lightly but firm enough to hold it down so that the needle is almost parallel to the surface of the slide. Needle 2, held with the other hand, also parallel to the surface of the slide and to needle 1, is now placed on the head or the proboscis and with sufficient pressure to hold but not crush the head. Carefully pull the head intermittently from the thorax. The secret of pulling out the lobes of the salivary glands lies in the slowness of traction on the head. The longer one can keep the head and the thorax within 1 to 2 millimeters distant from each other during the traction, the greater are the chances of success. During this stage both hands should rest on the table. When properly done, one will see white specks, the salivary glands, the œsophagus, and sometimes air bubbles between the head and the thorax floating in salt solution. To be sure of success, one should examine from time to time the region of the neck during this step. Once the glands are pulled out of the thorax, they are cut from the head at its junction with the needle. If one fails to get the glands with the head, he should proceed to pull out the stomach, and then return to the thorax and tease out the salivary glands by tearing carefully with the two needles the region of the thorax nearest the first coxæ with repeated examination under a low power. The salivary glands are easily recognized as two highly refractile sausage-shaped structures, each of which has

three lobes. A total of seven lobes in one insect has been observed twice.

The stomach is isolated in the same way as the salivary glands. Needle 1 is applied to the thorax with the abdomen in salt solution. Needle 2 is applied at about the caudal fourth or third of the abdomen and careful intermittent traction applied with needle 2. The abdominal casing will break at the point of application of needle 2 and expose the intestine, Malphigian tubules, and ova, if any. Should the abdominal casing fail to break at the point where needle 2 is applied, a puncture on its edge will start the break. Further traction will reveal the whole midgut and often a large portion of the entire foregut. Sometimes the abdomen breaks off at its junction with the thorax before the stomach is exposed. In that case needle 1 is applied at the cephalic third or fourth of the abdomen. Much pressure in the caudal third or fourth may sever that part of the abdomen without exposing the midgut. In that case the abdominal casing is torn on the edge and carefully pulled off the stomach. In a distended abdomen filled with blood or ova careful pressure, rolling the needle, from the cephalic to the caudal portion will press out the stomach and all. Repeated examination under the microscope during the process of dissection is very important.

It is preferable that the salivary glands be removed first, as the severed œsophagus will facilitate subsequent traction on and isolation of the stomach.

Oöcyst.—The nodular corrugations characteristic of a freshly isolated stomach from a recently killed mosquito should not be confused with oöcysts. Cysts have different refraction from the stomach tissue proper, and are uneven in distribution. They are best seen under a cover glass which is lightly pushed while the stomach is under view. The cyst on reaching a profile position will appear to be a distinct and complete spherical body with a wall and attached to the outer surface of the gut, while contractile corrugations are half spheres and regular in distribution. Small cysts may contain only spherical hyaline bodies, while the larger ones are filled with granules, bacillary structures, or spindles. A positive stomach may be preserved and mounted in 3 to 5 per cent formalin and the cover slip ringed with vaseline.

Sporozoites.—An infected salivary gland very frequently ruptures during the process of isolation. The sporozoites are

easily identified even with a ⅔ objective as numerous highly refractile bent rods, "vibrio-like," pouring from the ruptured side of a lobe. Before discarding the salivary gland as negative, apply a cover glass, press lightly, and push the cover glass to one side. If sporozoites are present, they will be discharged from the crushed gland. For the study of the morphology of the sporozoites, the cover glass is lifted and both the slide and the cover glass are allowed to dry. Treated with absolute methyl alcohol for a few minutes, washed in distilled water and stained with Giemsa, preferably a weaker solution than the one used for blood smears if one attempts to demonstrate the sporozoites within the gland. Even then, gland cells usually take a deeper stain and obliterate the contained sporozoites. Isolated sporozoites, however, could easily be identified as slender, usually bent, spindles at least 10 microns in length, often much longer, with tapering ends, blue cytoplasm, and a red nucleus.

The specimens successfully dissected from September 1 to December 31, 1927, and the positives found are distributed as to species as shown in Table 1.

TABLE 1.—*Number of mosquitoes dissected, by species.*

Species.	Number.	Stomach positive.	Per cent positive.	Salivary gland positive.	Per cent positive.
Anopheles minimus	2,283	19	0.83	8	0.35
Anopheles hyrcanus	77	0	.0	0	.0
Anopheles barbirostris	60	0	.0	0	.0
Anopheles rossii	41	0	.0	0	.0
Anopheles karwari	27	0	.0	0	.0
Anopheles tesselatus	5	0	.0	0	.0
Anopheles fuliginosus	194	0	.0	0	.0
Anopheles philippinensis	5	0	.0	0	.0
Anopheles maculatus	1	0	.0	0	.0

From these observations it is evident that *Anopheles minimus* is a natural vector of malaria in the Philippines. This species can be controlled by dusting streams with a mixture of Paris green and road dust, so that engineering projects have not been shown to be necessary in the control of malaria in the Philippines.

SUMMARY

1. Circumstantial evidence in about eighty malarious places and direct evidence in the second worst of these places, point to *Anopheles minimus* as the natural vector of malaria so far

found in the Philippines. It is possible that other species may, in certain localities, also transmit malaria under natural conditions, but this has to be shown by further observations.

2. The percentage of positives for natural infection of *A. minimus* are 0.83 per cent for the stomach and 0.35 per cent for the salivary gland.

3. The findings justify "species control" which limits larval control to streams and irrigation ditches breeding *A. minimus*. Engineering projects are not, as far as the present surveys indicate, necessary in the control of malaria in the Philippines.

4. The "wild" nature of *A. minimus* precludes campaign against the adults. Traps have not yet been tried.

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ILLUSTRATIONS

[Microphotographs by the Bureau of Science.]

PLATE 1

FIG. 1. *Anopheles minimus* Theobald; normal stomach, showing contractile corrugations of the stomach wall and a small amount of blood. Fixed and mounted in 3 per cent formalin. × 100.

2. *Anopheles minimus* Theobald; stomach with oöcyst. Fixed and mounted as in fig. 1, but slightly flattened by the weight of the cover glass. × 100.

3. *Anopheles minimus* Theobald; stomach filled with blood and many young oöcysts. Fixed in Bouin's fluid and stained with iron ammonium sulphate and hæmatoxylin. × 100.

PLATE 2

FIG. 4. *Anopheles minimus* Theobald; stomach with four young oöcyst; fresh, mounted in salt solution, flattened and distorted by the cover glass. × 450.

5. *Anopheles minimus* Theobald; stomach, showing one more-mature oöcyst in the center with granular material and distinct cyst wall. Fixed in Zenker's fluid and stained with iron ammonium sulphate and hæmatoxylin. × 1000.

PLATE 3

FIG. 6. *Anophels minimus* Theobald; the same specimen as that of fig. 5, showing the matured cysts and sporozoites.

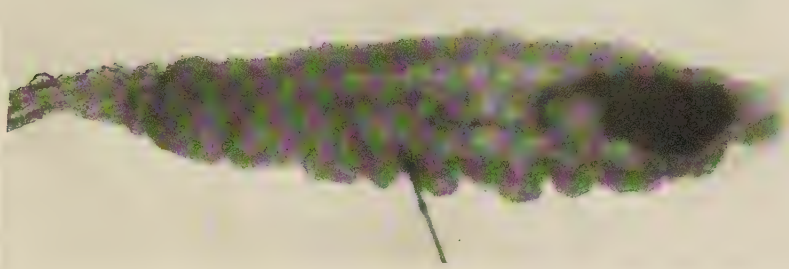
7. *Anopheles minimus* Theobald; salivary gland, showing sporozoites. Fixed in formalin and stained with hæmatoxylin-eosin. × 600.

8. *Anopheles minimus* Theobald; a lobe of the salivary gland, showing most of the cells filled with sporozoites. Fixed in absolute alcohol and stained with iron ammonium sulphate and hæmatoxylin. × 1000.

PLATE 4

FIG. 9. *Anopheles minimus* Theobald; isolated sporozoites from a ruptured lobe of the salivary glands. Fixed in Zenker's fluid and stained with Delafield hæmatoxylin. × 1000.

10. Domestic *Culex*, section of the thoracic ganglion. Fixed in alcohol and stained with hæmatoxylin-eosin, showing the nuclei of the neurones which Banks mistook for sporozoites.



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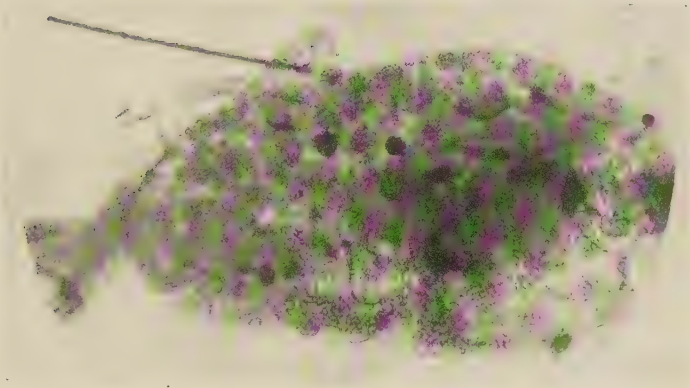

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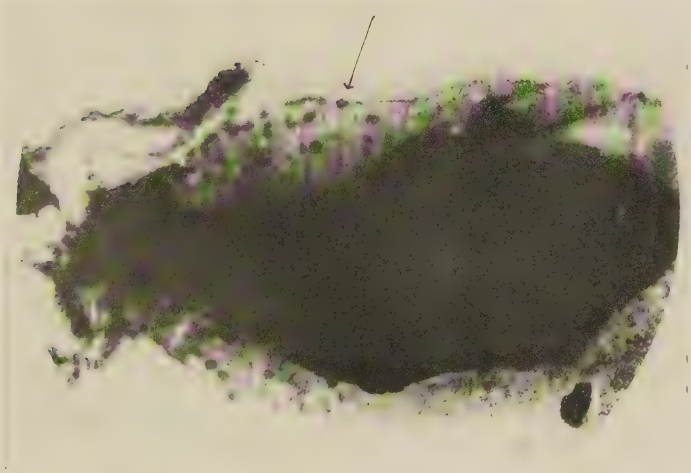

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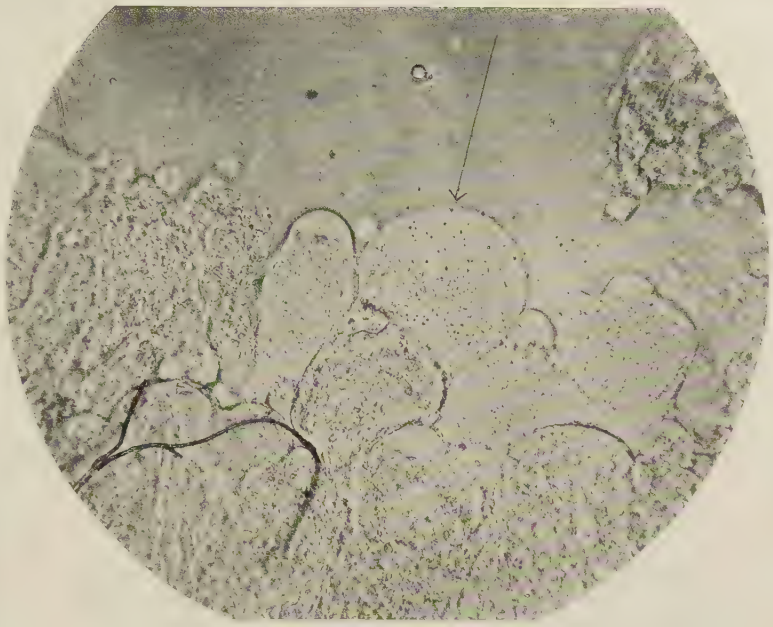
PLATE 1.



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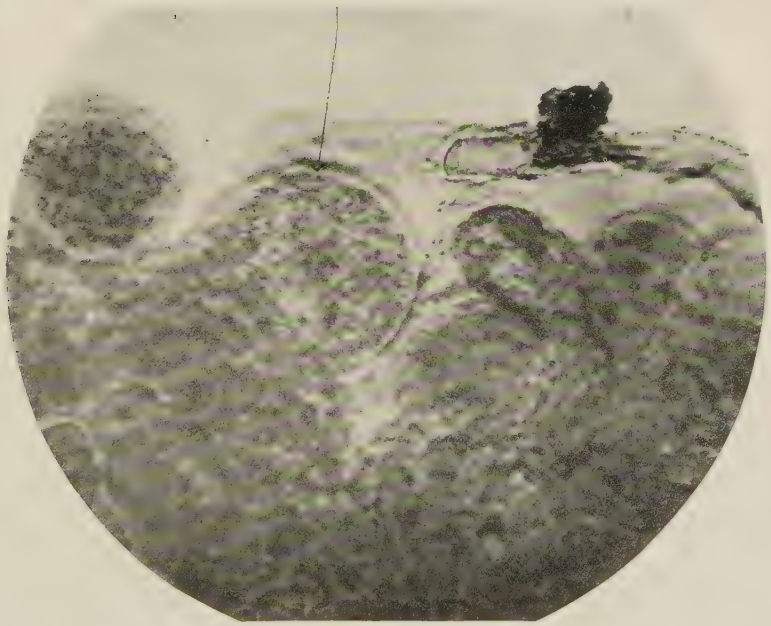

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PLATE 2.

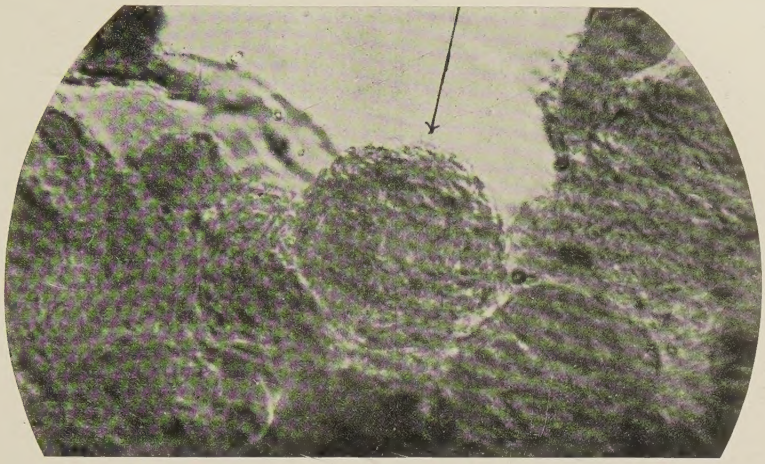

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PLATE 3.

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PLATE 4.